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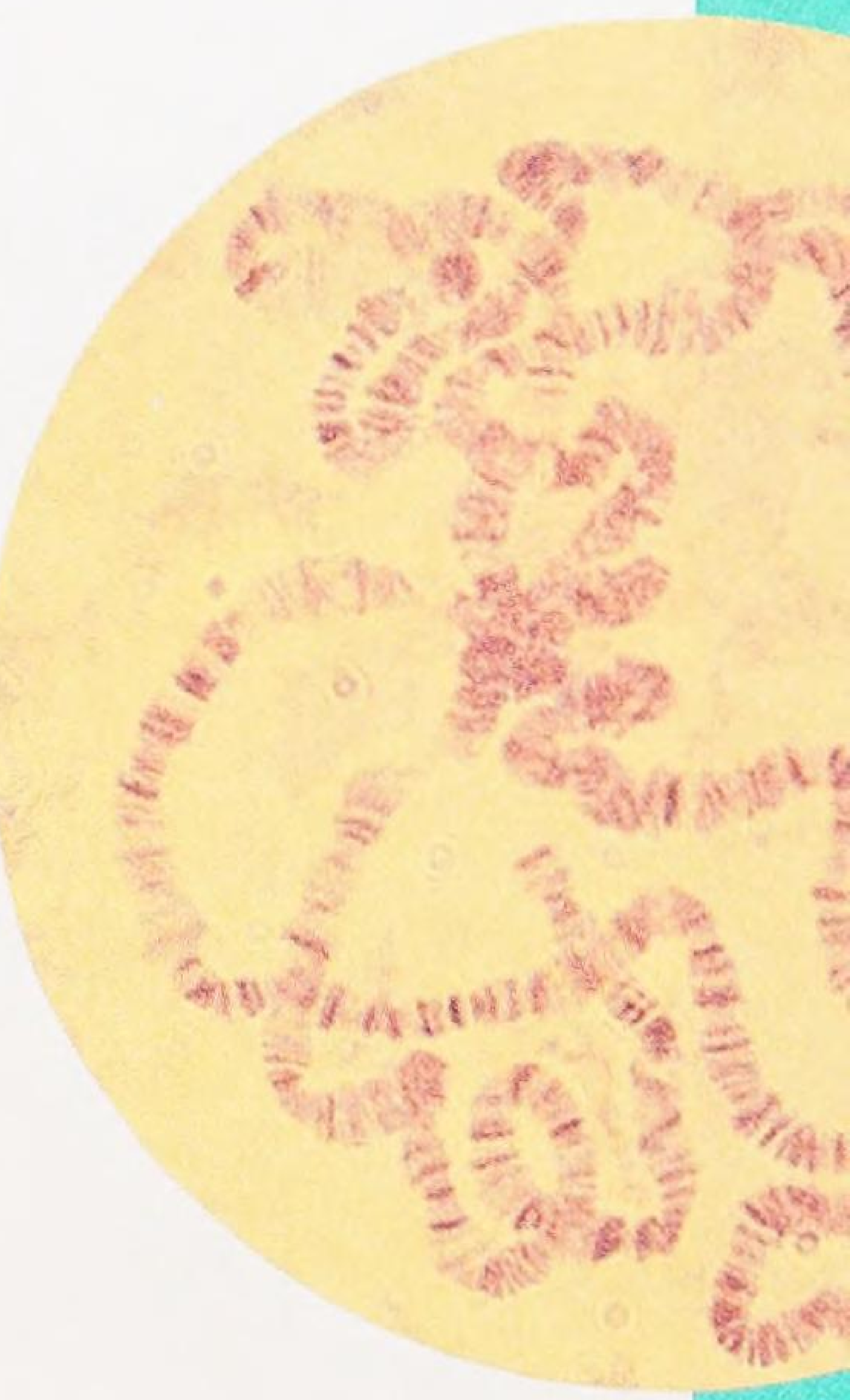

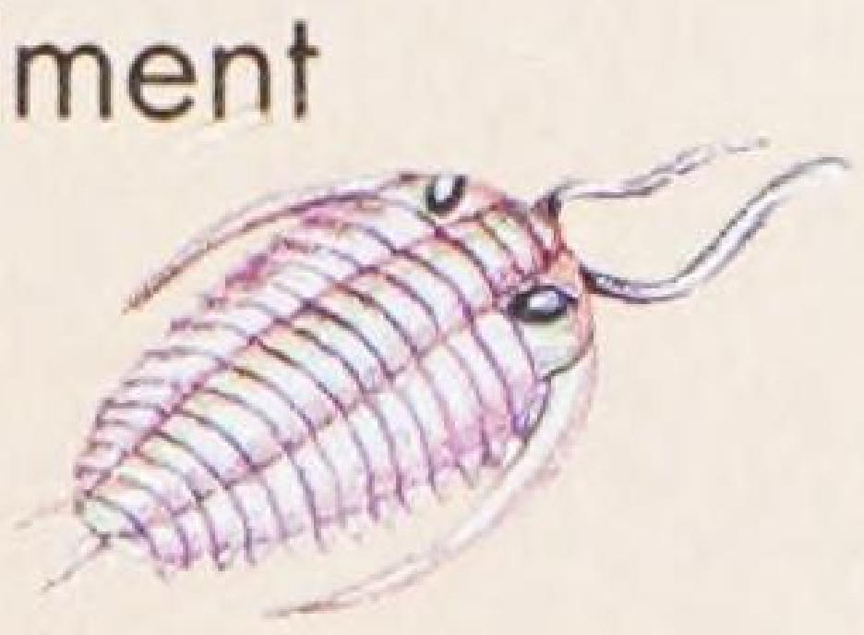

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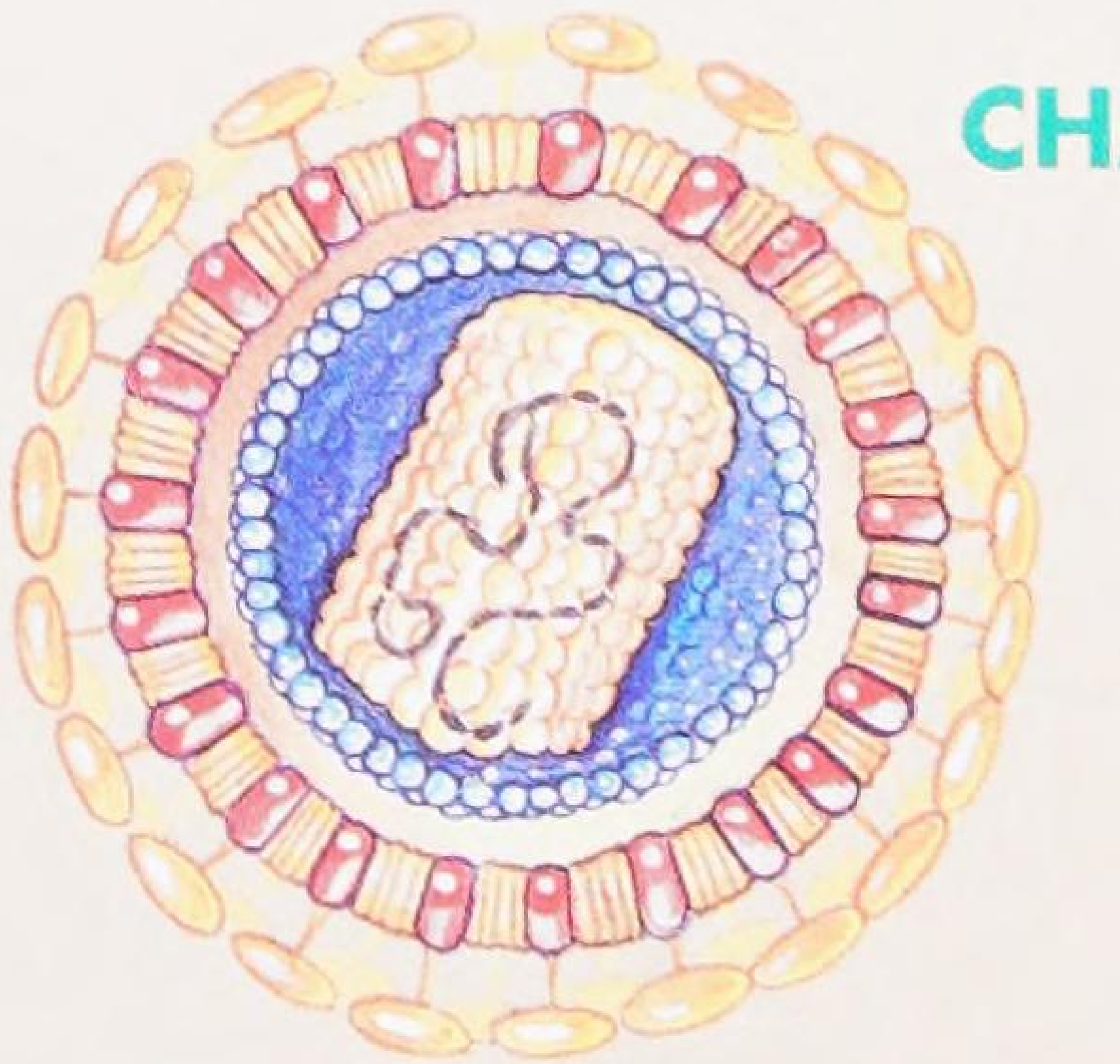

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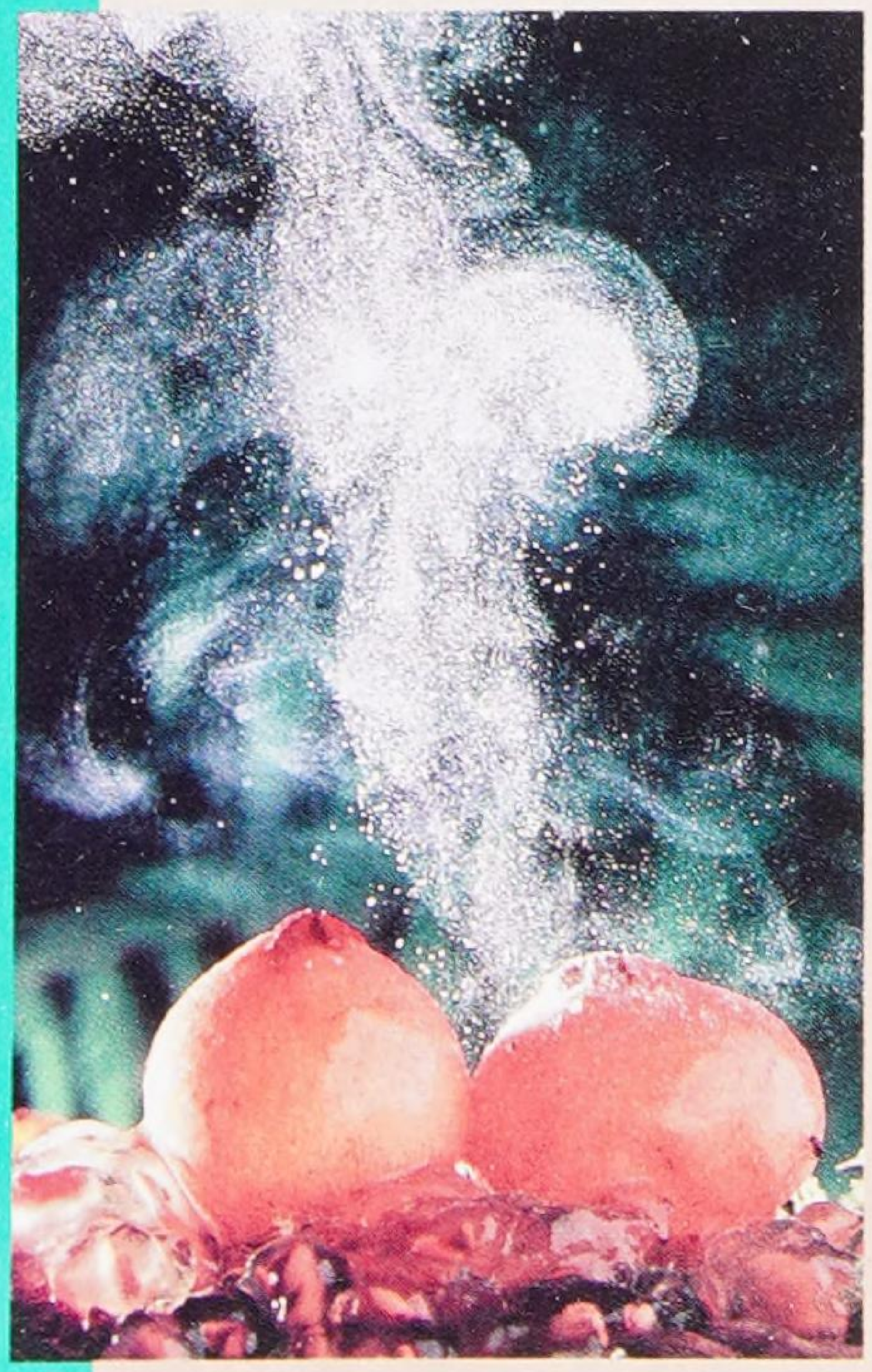

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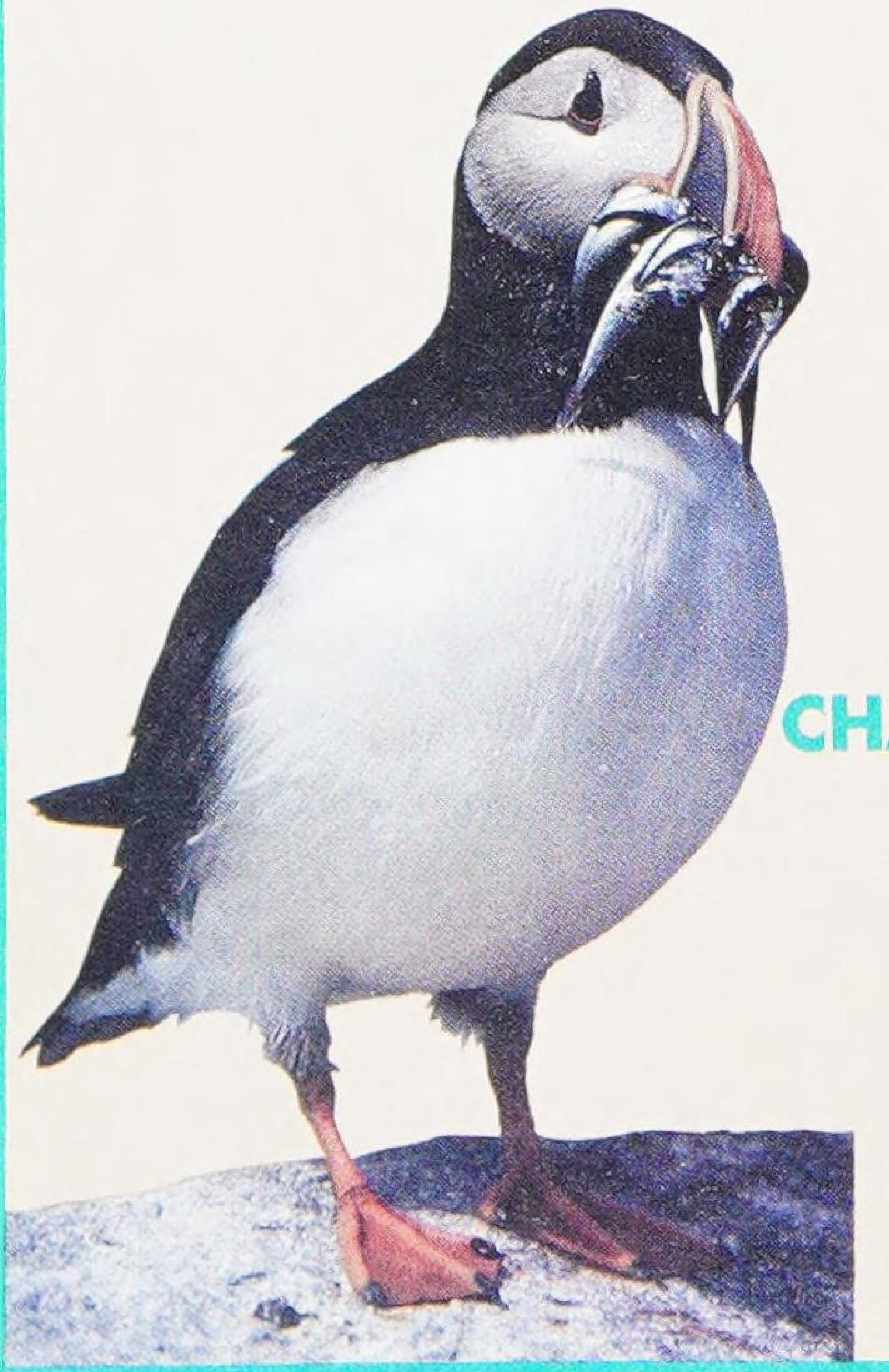

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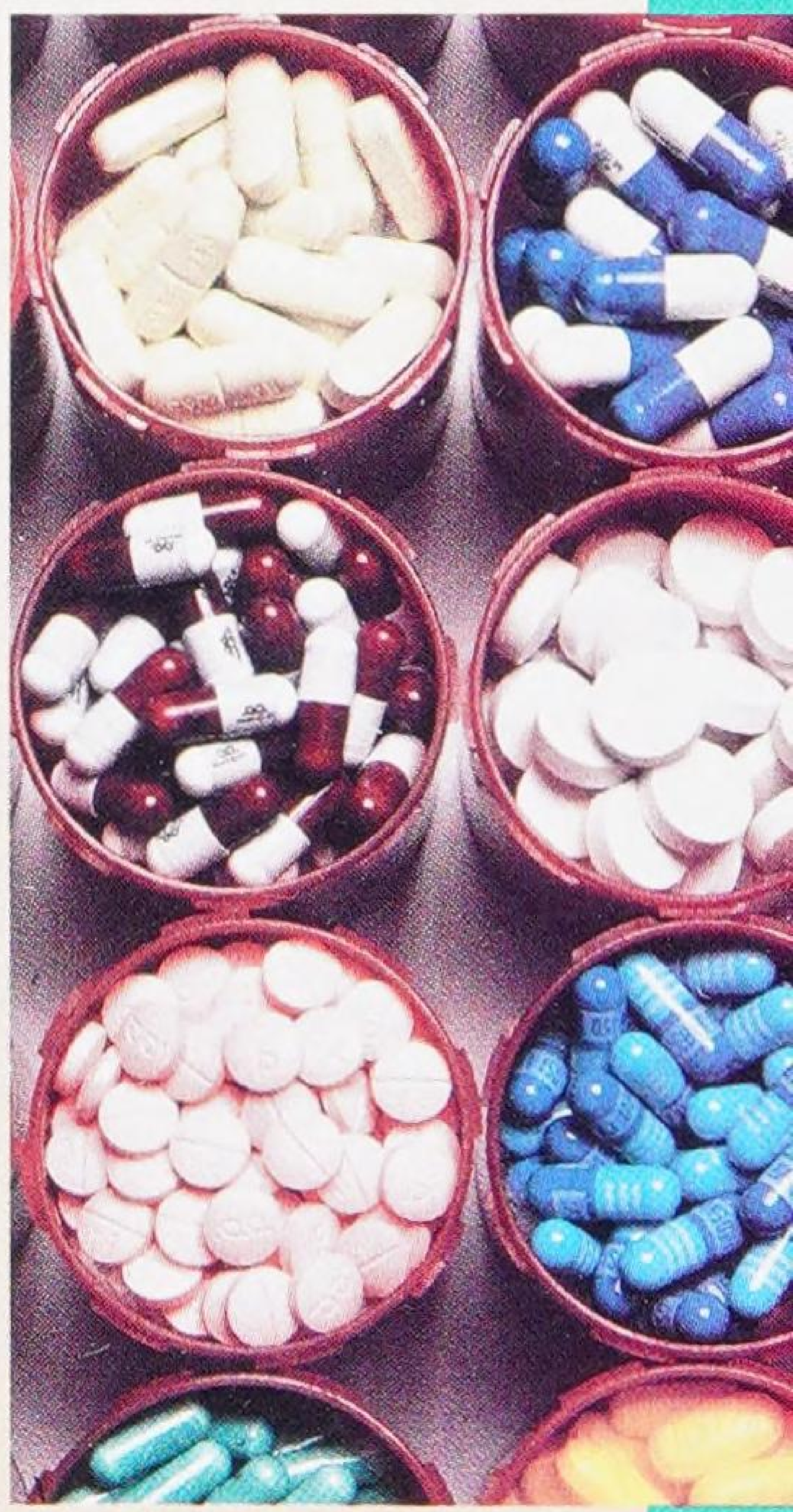

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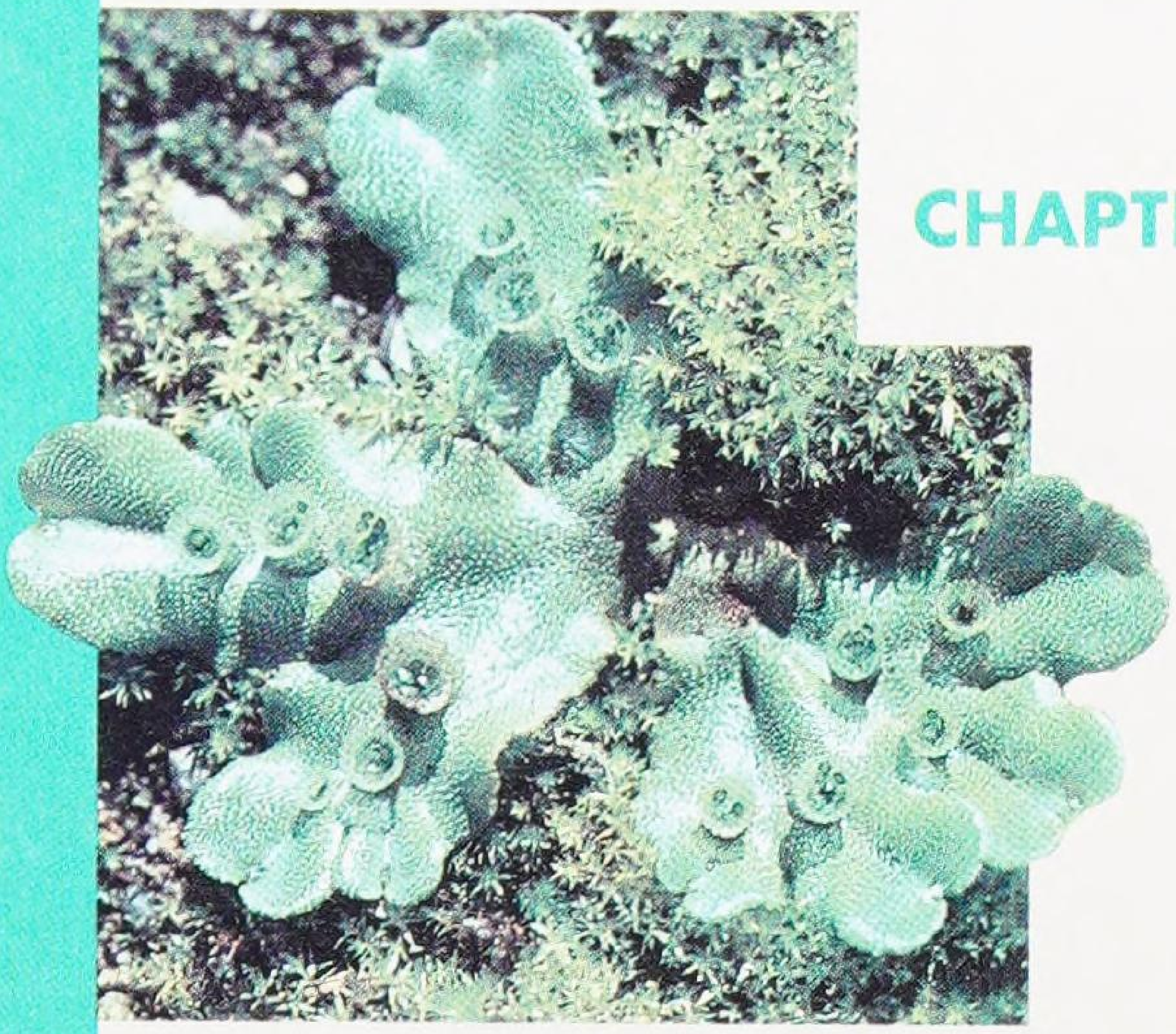

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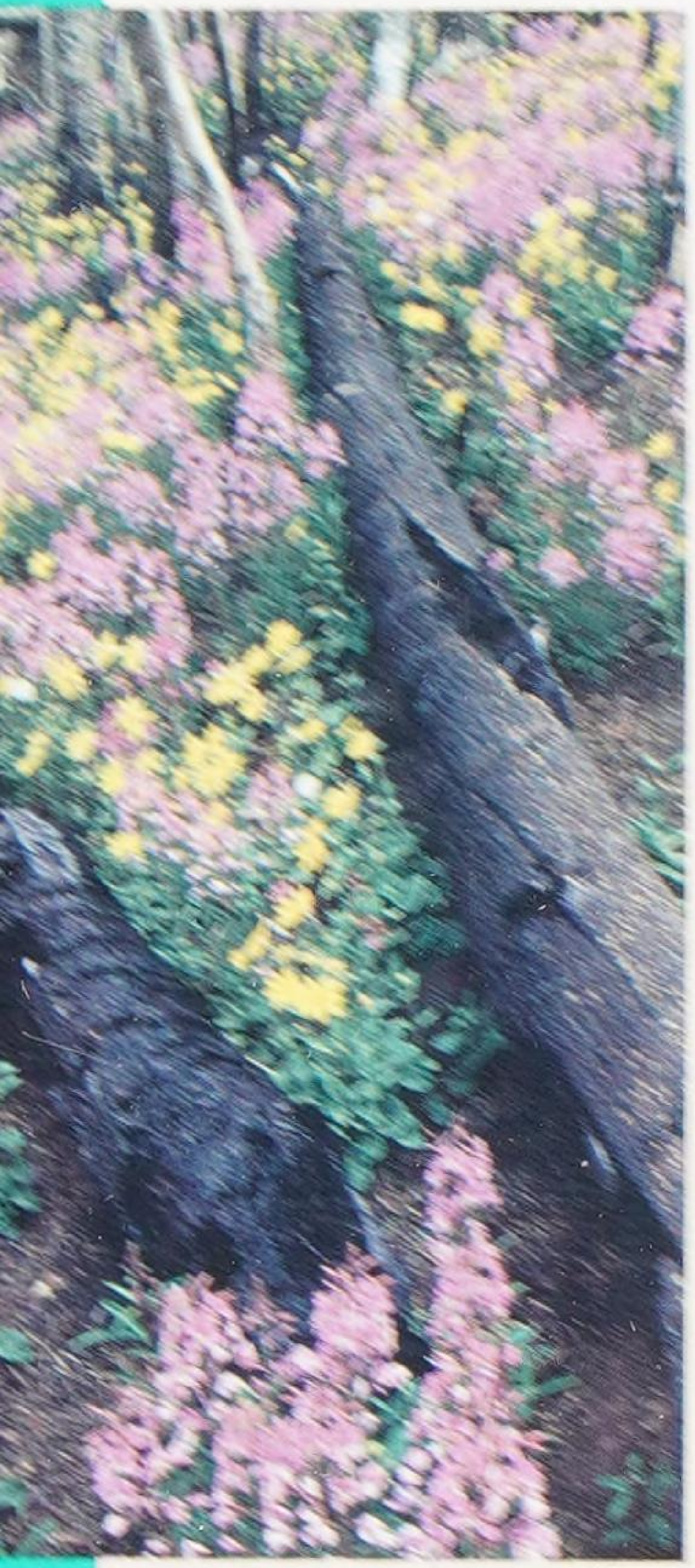

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UNIT 3: Simple Living Things 222
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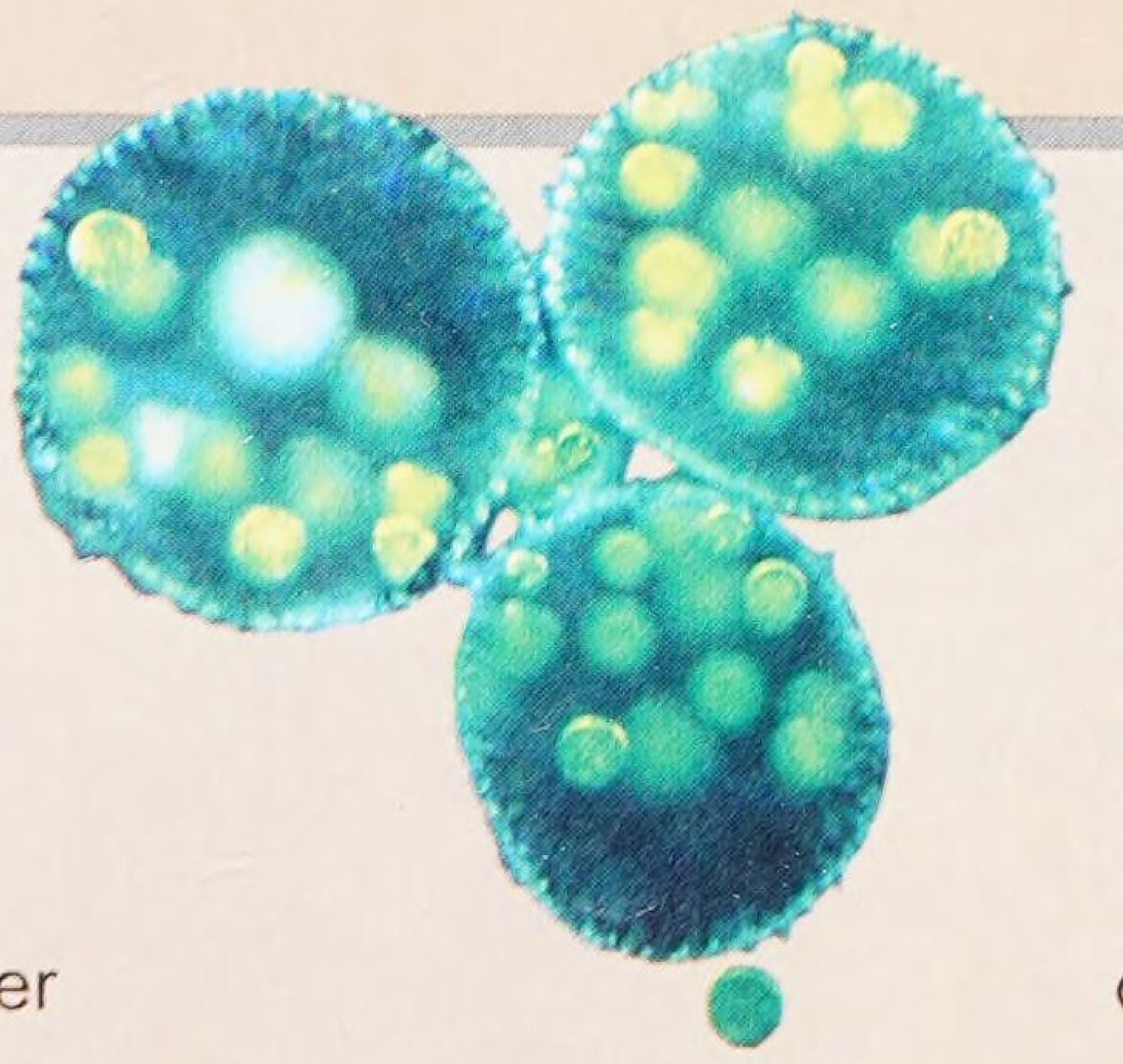
UNIT 8: Ecology 666
Oceanography, Social Studies, History, Meteorology, Chemistry

CAREERS



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USING MERRILL LIFE SCIENCE

Life Science is an everyday experience. It's a subject you're familiar with because every part of your day is based upon principles of life science… the simple act of walking involves your muscles to move your body, your nervous system to tell your muscles what to do and where you want to go, and your circulatory system to transport nutrients, energy, and oxygen to all parts of your body. Depending on where you walk, you may encounter a variety of insects, plants, and animals that are living their lives also based upon principles of life science. **Merrill Life Science** will help you understand life science principles and recognize how they affect you and the life around you everyday.

a quick tour of your textbook

What's happening here? Have you ever seen a raft setting on the tops of trees? Each unit begins with thought-provoking photographs that will make you wonder. The unit introduction then explains what is happening in the photographs and how the two relate to each other and to the content of the unit. What is a raft doing on the tops of trees? Read the opener to Unit 4 to find out.

UNIT 4 PLANTS

What's Happening Here?

How do you collect specimens 150 meters in the air? In 1989, a daring group of French scientists cleverly solved this problem by lowering a raft onto the trees of the rain forest from the air. The scientists tethered themselves to the raft for safety and then worked, ate, and slept in their unique, elevated research lab. What did they hope to learn? As rain forests are destroyed at an increasing rate, there is less time to learn about their treasures. The raft helped the scientists to find out if the plants and animals that live on the floor of the forest are different from those at home in the upper story.

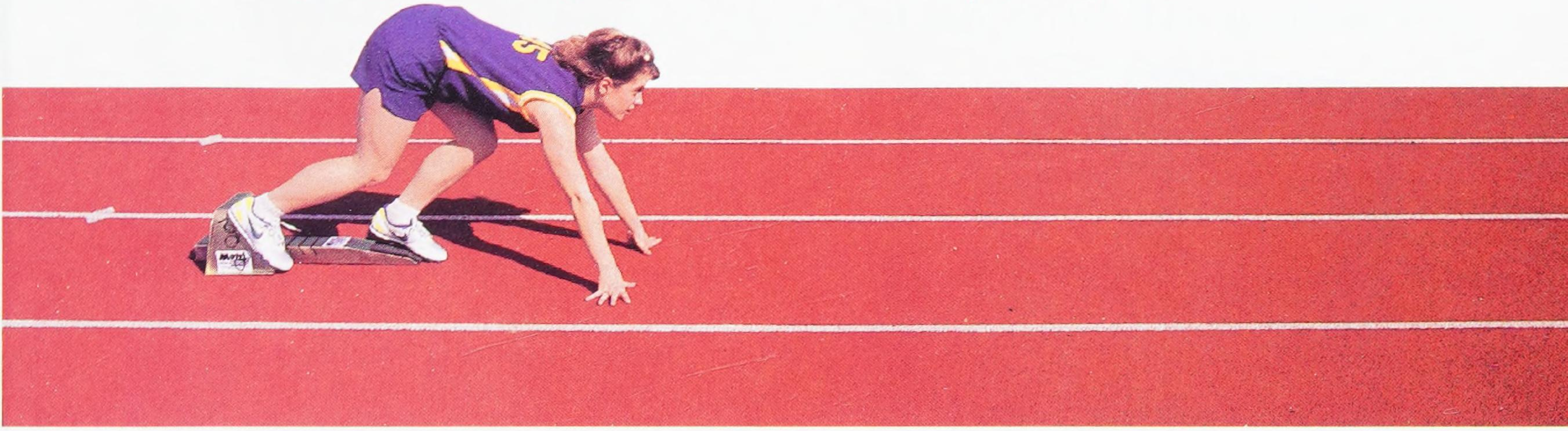
UNIT CONTENTS

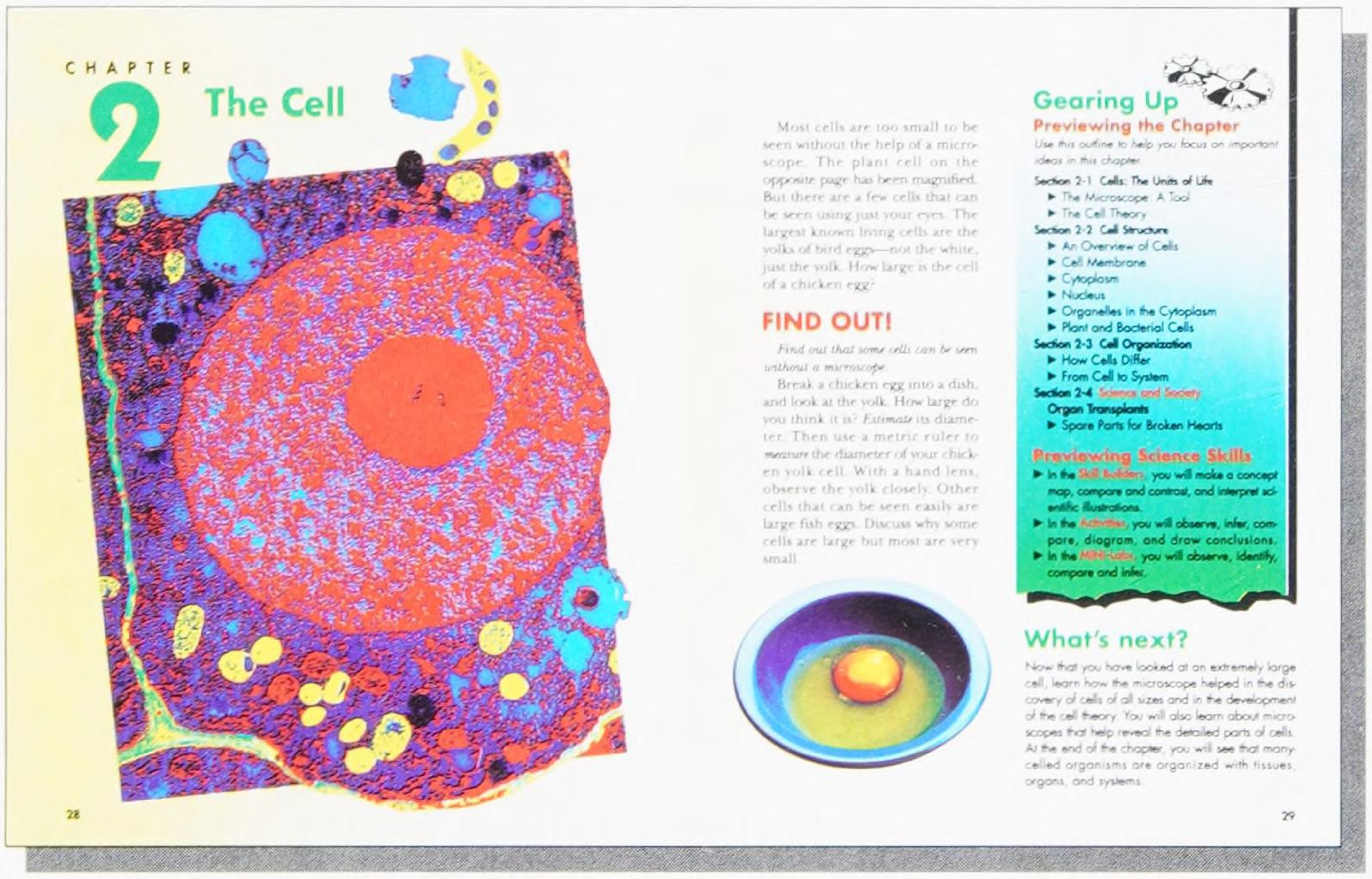
Chapter 10	Introduction to Plants
Chapter 11	The Seed Plants
Chapter 12	Plant Processes

226

227

It's clearly organized to get you started and keep you going.





CHAPTER 2

The Cell

28

Most cells are too small to be seen without the help of a microscope. The plant cell on the opposite page has been magnified. But there are a few cells that can be seen using just your eyes. The largest known living cells are the yolks of bird eggs—not the white, just the yolk. How large is the cell of a chicken egg?

FIND OUT!

Find out that some cells can be seen without a microscope.

Break a chicken egg into a dish, and look at the yolk. How large do you think it is? *Estimate* its diameter. Then use a metric ruler to *measure* the diameter of your chicken yolk cell. With a hand lens, observe the yolk closely. Other cells that can be seen easily are large fish eggs. Discuss why some cells are large but most are very small.

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 2-1 Cells: The Units of Life
- The Microscope: A Tool
- The Cell Theory

Section 2-2 Cell Structure
- An Overview of Cells
- Cell Membrane
- Cytoplasm
- Nucleus
- Organelles in the Cytoplasm
- Plant and Bacterial Cells

Section 2-3 Cell Organization
- How Cells Differ
- From Cell to System

Section 2-4 Science and Society
Organ Transplants
- Spare Parts for Broken Hearts

Previewing Science Skills
- In the Skill Builders, you will make a concept map, compare and contrast, and interpret scientific illustrations.
- In the Activities, you will observe, infer, compare, diagram, and draw conclusions.
- In the MINI-Labs, you will observe, identify, compare and infer.

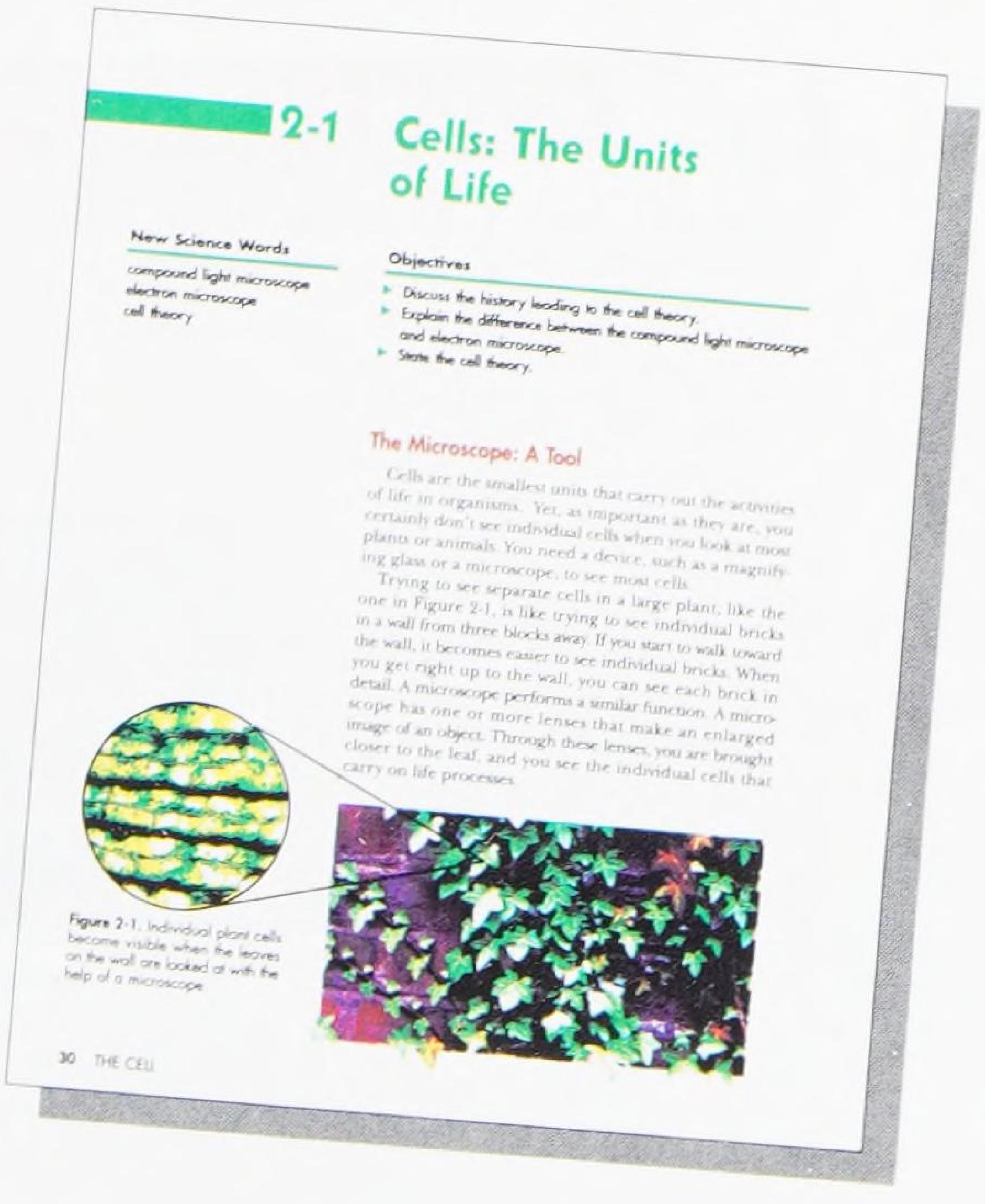
What's next?

Now that you have looked at an extremely large cell, learn how the microscope helped in the discovery of cells of all sizes and in the development of the cell theory. You will also learn about microscopes that help reveal the detailed parts of cells. At the end of the chapter, you will see that many-celled organisms are organized with tissues, organs, and systems.

29

As you begin each new chapter, use the **Gearing Up** to preview what topics are covered and how they are organized. You will also preview the skills you will use in this chapter.

After you've performed the **FIND OUT** activity and previewed the chapter, you're ready to further explore the topics ahead. Read **What's next** to see what's ahead.



2-1 Cells: The Units of Life

New Science Words

compound light microscope
electron microscope
cell theory

Objectives
- Discuss the history leading to the cell theory.
- Explain the difference between the compound light microscope and electron microscope.
- State the cell theory.

The Microscope: A Tool

Cells are the smallest units that carry out the activities of life in organisms. Yet, as important as they are, you certainly don't see individual cells when you look at most plants or animals. You need a device, such as a magnifying glass or a microscope, to see most cells.

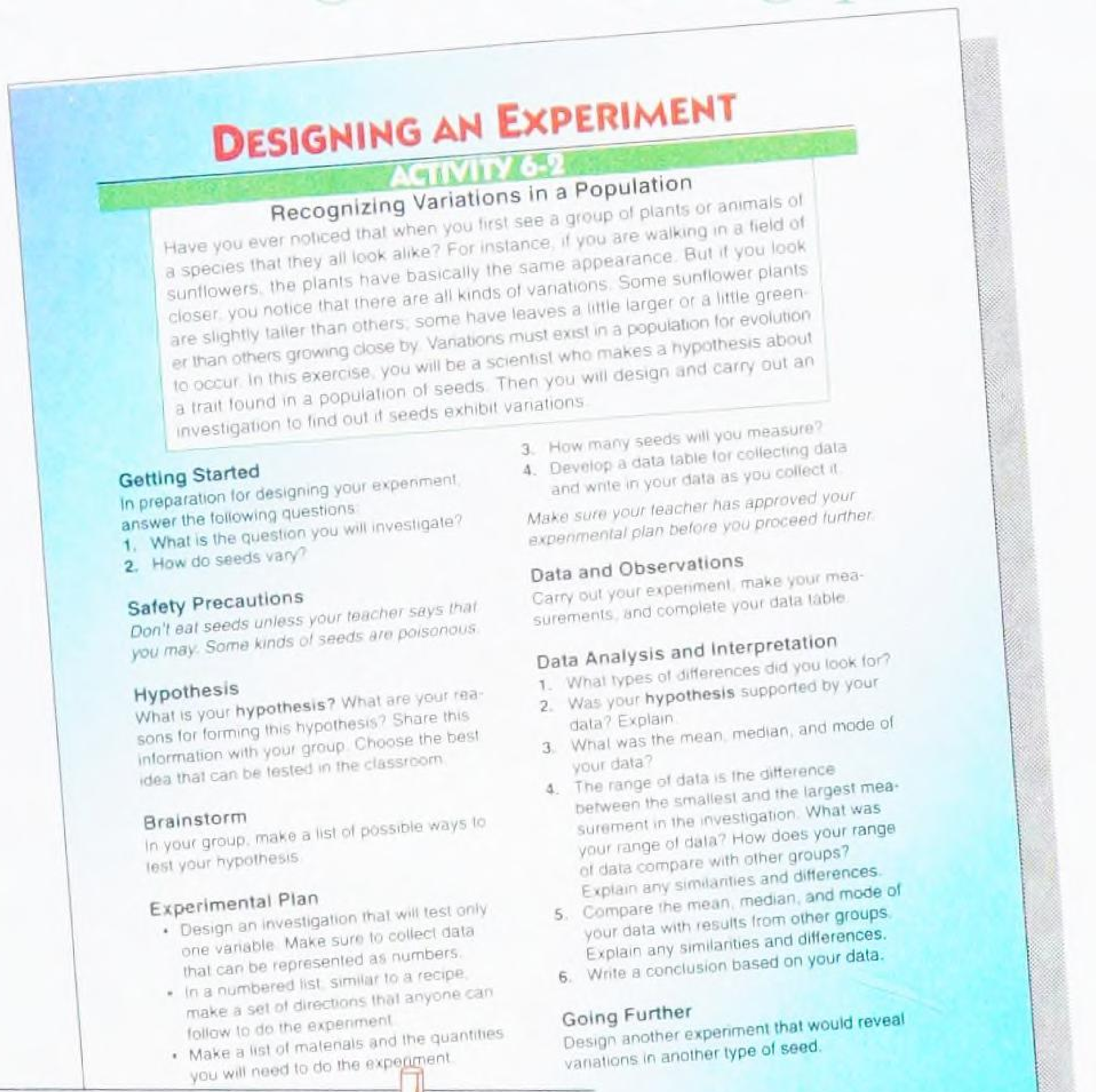
Trying to see separate cells in a large plant, like the one in Figure 2-1, is like trying to see individual bricks in a wall from three blocks away. If you start to walk toward the wall, it becomes easier to see individual bricks. When you get right up to the wall, you can see each brick in detail. A microscope performs a similar function. A microscope has one or more lenses that make an enlarged image of an object. Through these lenses, you are brought closer to the leaf, and you see the individual cells that carry on life processes.

Figure 2-1. Individual plant cells become visible when the leaves on the wall are looked at with the help of a microscope.

30 THE CELL

Chapters are organized into three to five numbered sections. The **Objectives** at the beginning of the numbered section tell you what major topics you'll be covering and what you should expect to learn about them. The **New Science Words** are also listed in the order in which they appear in the section.

Experience science by observing, experimenting, and asking questions.



DESIGNING AN EXPERIMENT

ACTIVITY 6-2

Recognizing Variations in a Population

Have you ever noticed that when you first see a group of plants or animals of a species that they all look alike? For instance, if you are walking in a field of sunflowers, the plants have basically the same appearance. But if you look closer, you notice that there are all kinds of variations. Some sunflower plants are slightly taller than others; some have leaves a little larger or a little greener than others growing close by. Variations must exist in a population for evolution to occur. In this exercise, you will be a scientist who makes a hypothesis about a trait found in a population of seeds. Then you will design and carry out an investigation to find out if seeds exhibit variations.

Getting Started

In preparation for designing your experiment, answer the following questions:

1. What is the question you will investigate?
2. How do seeds vary?

Safety Precautions

Don't eat seeds unless your teacher says that you may. Some kinds of seeds are poisonous.

Hypothesis

What is your **hypothesis?** What are your reasons for forming this hypothesis? Share this information with your group. Choose the best idea that can be tested in the classroom.

Brainstorm

In your group, make a list of possible ways to test your hypothesis.

Experimental Plan

- Design an investigation that will test only one variable. Make sure to collect data that can be represented as numbers.
- In a numbered list, similar to a recipe, make a set of directions that anyone can follow to do the experiment.
- Make a list of materials and the quantities you will need to do the experiment.

3. How many seeds will you measure?
4. Develop a data table for collecting data and write in your data as you collect it.

Make sure your teacher has approved your experimental plan before you proceed further.

Data and Observations

Carry out your experiment, make your measurements, and complete your data table.

Data Analysis and Interpretation

1. What types of differences did you look for?
2. Was your **hypothesis** supported by your data? Explain.
3. What was the mean, median, and mode of your data?
4. The range of data is the difference between the smallest and the largest measurement in the investigation. What was your range of data? How does your range of data compare with other groups? Explain any similarities and differences.
5. Compare the mean, median, and mode of your data with results from other groups. Explain any similarities and differences.
6. Write a conclusion based on your data.

Going Further

Design another experiment that would reveal variations in another type of seed.

MINI-Lab

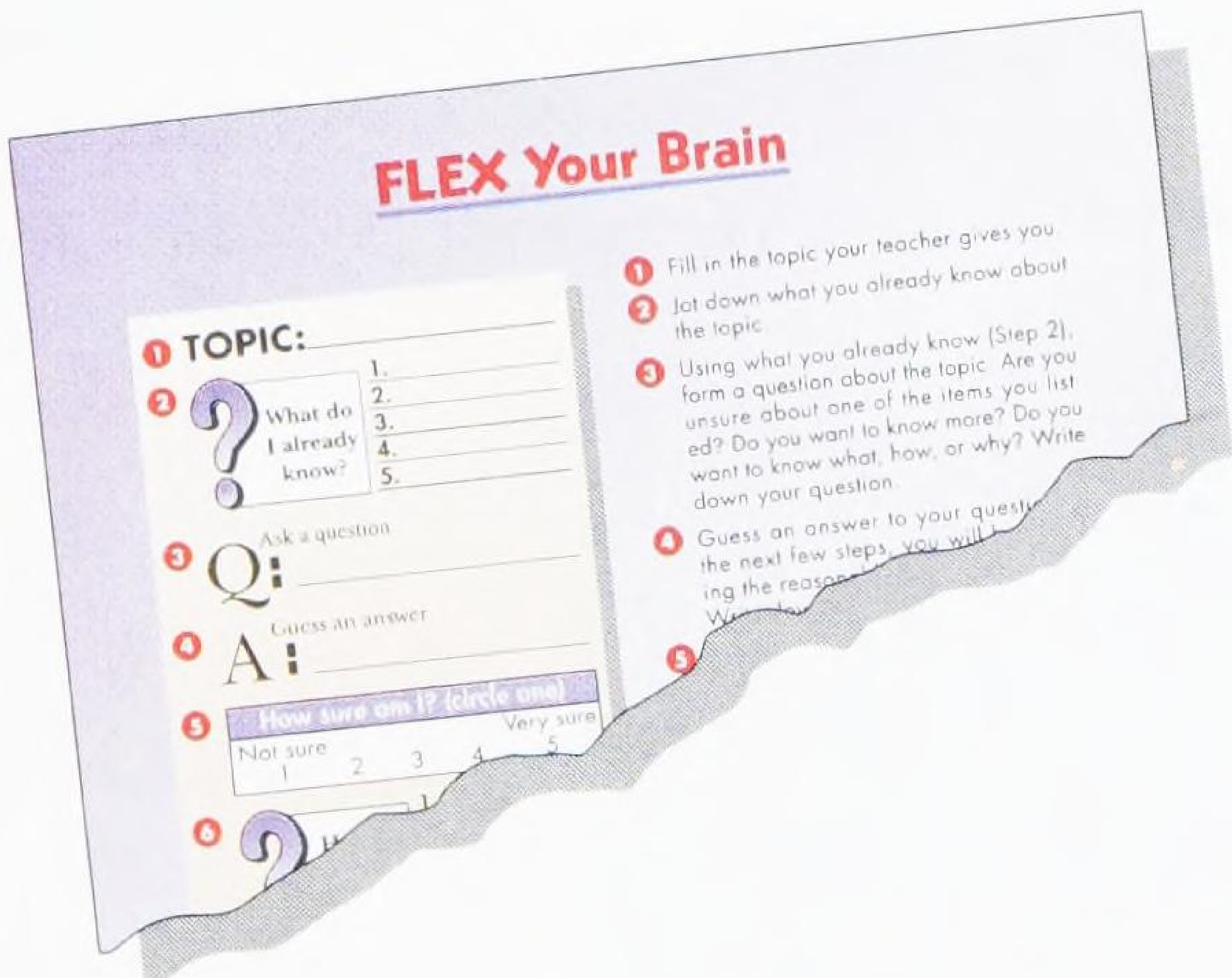
What organisms are found in an ecosystem?

Choosing an ecosystem you are familiar with, such as a stream, garden plot, or empty lot, *identify* the organisms found there. Make a list of all the populations you can see in the ecosystem. *Infer* the niche of each species in the community.

Science is more than words in a book. The Activities and MINI-Labs in each chapter give you the chance to explore and investigate the science topics hands on.

In the **Activities,** you'll use household items and laboratory equipment as you follow step-by-step procedures. At the end of each Activity are questions that ask you to analyze what you've done. In several instances, you will design experiments and carry them out to test your own hypotheses.

Most **MINI-Labs** are designed so you can do them on your own or with friends outside of the science classroom using materials you find around the house. Doing a MINI-Lab is an easy and fun way to extend your knowledge about the topics you're studying.



FLEX Your Brain

① TOPIC:

② What do I already know?
1.
2.
3.
4.
5.

③ Q: Ask a question

④ A: Guess an answer

⑤ How sure am I? (circle one)
Not sure 1 2 3 4 5 Very sure

⑥

① Fill in the topic your teacher gives you.

② Jot down what you already know about the topic.

③ Using what you already know (Step 2), form a question about the topic. Are you unsure about one of the items you listed? Do you want to know more? Do you want to know what, how, or why? Write down your question.

④ Guess an answer to your questi the next few steps, you will ing the reaso

⑤

Flex Your Brain is a unique activity you can use to sharpen your critical thinking skills. Starting from what you already know about a science topic, you will apply a simple ten-step procedure to extend your knowledge about the topic from a perspective that interests you.

Each **Problem Solving** feature gives you a chance to solve a real life problem.

PROBLEM SOLVING

Why Isn't Earth Covered with Pumpkins and Pike?

Assume that there are 70 seeds in one pumpkin and that this is the typical number for the species. The 70 seeds are planted and each seed grows into a plant that produces two pumpkins. The first year 70 seeds are planted. The number of seeds produced in three years can be calculated by multiplying the number of seeds times two pumpkins for each plant times 70 seeds in each pumpkin:

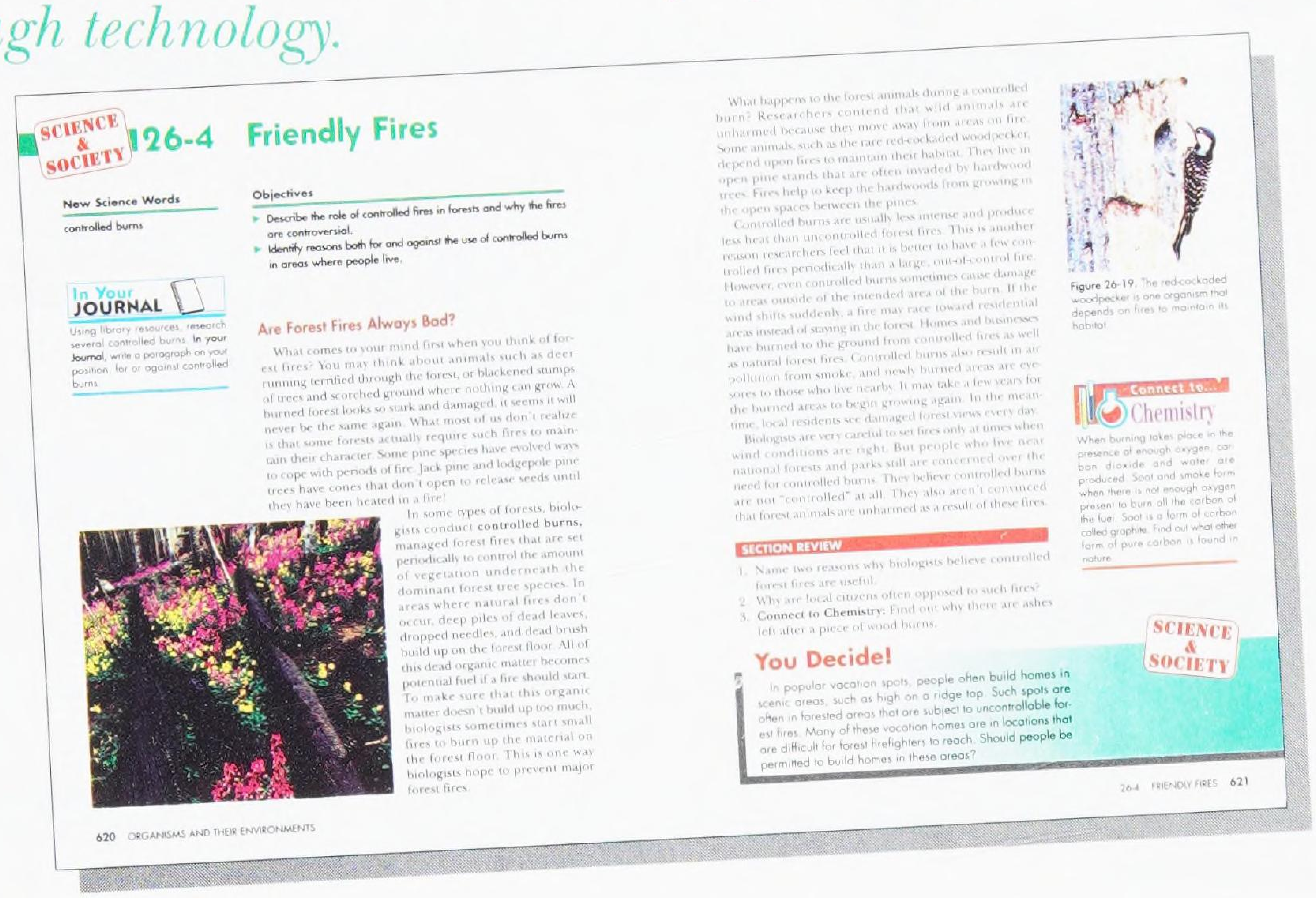
Year 1: 70 x 2 x 70 = 9800
Year 2: 9800 x 2 x 70 = 1 372 000
Year 3: 1 372 000 x 2 x 70
= 192 080 000 seeds

The largest possible number of offspring produced by one individual is known as the biotic potential of a species.

If the ovaries of a pike contain 42 000 eggs, all the eggs are fertilized and hatched, all the young survive to reproduce, and one-half of the young are females, how many pike would there be after two more generations?

Think Critically: Why is the maximum rate of biotic potential never reached?

Explore news-making issues, concerns about the environment, and how science shapes your world through technology.



SCIENCE & SOCIETY

26-4 Friendly Fires

New Science Words

controlled burns

Objectives

- Describe the role of controlled fires in forests and why the fires are controversial.
- Identify reasons both for and against the use of controlled burns in areas where people live.

In Your JOURNAL

Using library resources, research several controlled burns. **In your Journal**, write a paragraph on your position, for or against controlled burns.

Are Forest Fires Always Bad?

What comes to your mind first when you think of forest fires? You may think about animals such as deer running terrified through the forest, or blackened stumps of trees and scorched ground where nothing can grow. A burned forest looks so stark and damaged, it seems it will never be the same again. What most of us don't realize is that some forests actually require such fires to maintain their character. Some pine species have evolved ways to cope with periods of fire. Jack pine and lodgepole pine trees have cones that don't open to release seeds until they have been heated in a fire!

In some types of forests, biologists conduct **controlled burns**, managed forest fires that are set periodically to control the amount of vegetation underneath the dominant forest tree species. In areas where natural fires don't occur, deep piles of dead leaves, dropped needles, and dead brush build up on the forest floor. All of this dead organic matter becomes potential fuel if a fire should start. To make sure that this organic matter doesn't build up too much, biologists sometimes start small fires to burn up the material on the forest floor. This is one way biologists hope to prevent major forest fires.

620 ORGANISMS AND THEIR ENVIRONMENTS

What happens to the forest animals during a controlled burn? Researchers contend that wild animals are unharmed because they move away from areas on fire. Some animals, such as the rare red-cockaded woodpecker, depend upon fires to maintain their habitat. They live in open pine stands that are often invaded by hardwood trees. Fires help to keep the hardwoods from growing in the open spaces between the pines.

Controlled burns are usually less intense and produce less heat than uncontrolled forest fires. This is another reason researchers feel that it is better to have a few controlled fires periodically than a large, out-of-control fire. However, even controlled burns sometimes cause damage to areas outside of the intended area of the burn. If the wind shifts suddenly, a fire may race toward residential areas instead of staying in the forest. Homes and businesses have burned to the ground from controlled fires as well as natural forest fires. Controlled burns also result in air pollution from smoke, and newly burned areas are eyesores to those who live nearby. It may take a few years for the burned areas to begin growing again. In the meantime, local residents see damaged forest views every day.

Biologists are very careful to set fires only at times when wind conditions are right. But people who live near national forests and parks still are concerned over the need for controlled burns. They believe controlled burns are not "controlled" at all. They also aren't convinced that forest animals are unharmed as a result of these fires.

Figure 26-19. The red-cockaded woodpecker is one organism that depends on fires to maintain its habitat.

Connect to... Chemistry

When burning takes place in the presence of enough oxygen, carbon dioxide and water are produced. Soot and smoke form when there is not enough oxygen present to burn all the carbon of the fuel. Soot is a form of carbon called graphite. Find out what other form of pure carbon is found in nature.

SECTION REVIEW

1. Name two reasons why biologists believe controlled forest fires are useful.
2. Why are local citizens often opposed to such fires?
3. **Connect to Chemistry:** Find out why there are ashes left after a piece of wood burns.

You Decide!

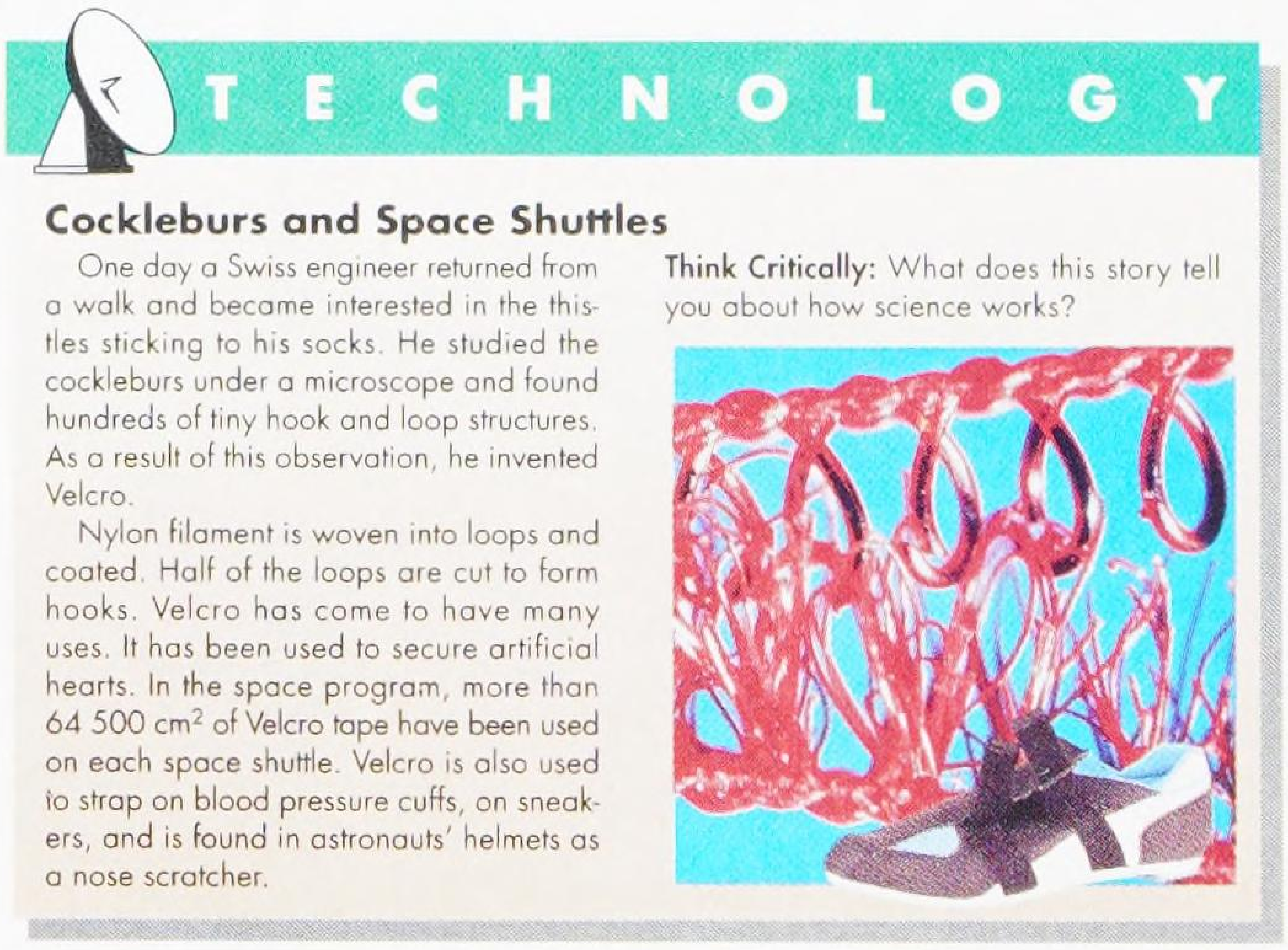
In popular vacation spots, people often build homes in scenic areas, such as high on a ridge top. Such spots are often in forested areas that are subject to uncontrollable forest fires. Many of these vacation homes are in locations that are difficult for forest firefighters to reach. Should people be permitted to build homes in these areas?

SCIENCE & SOCIETY

26-4 FRIENDLY FIRES 621

The impact of science on society directly affects you. In the **Science and Society** section in each chapter, you'll learn about an issue that's affecting the world around you. The topics you'll read about are controversial, and you'll explore them from several sides. Then, you'll have a chance to express your opinion in the You Decide feature that follows.

In the **Technology** feature in each chapter, you'll read about recent discoveries, newly developed instruments, and applications of technology that have shaped our world and furthered our knowledge.



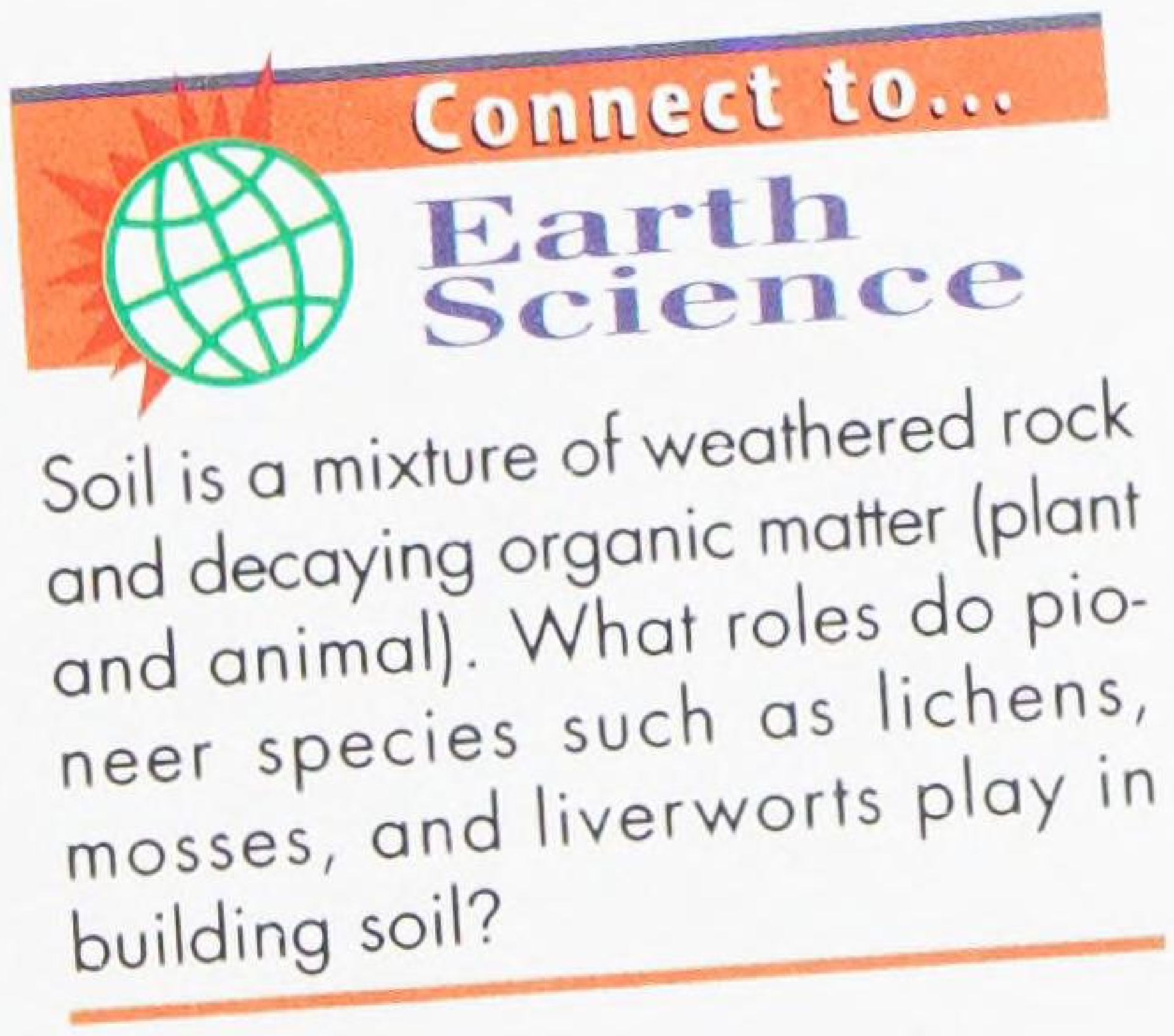
TECHNOLOGY

Cocklebursand Space Shuttles

One day a Swiss engineer returned from a walk and became interested in the thistles sticking to his socks. He studied the cockleburs under a microscope and found hundreds of tiny hook and loop structures. As a result of this observation, he invented Velcro.

Nylon filament is woven into loops and coated. Half of the loops are cut to form hooks. Velcro has come to have many uses. It has been used to secure artificial hearts. In the space program, more than 64 500 cm^2 of Velcro tape have been used on each space shuttle. Velcro is also used to strap on blood pressure cuffs, on sneakers, and is found in astronauts' helmets as a nose scratcher.

Think Critically: What does this story tell you about how science works?

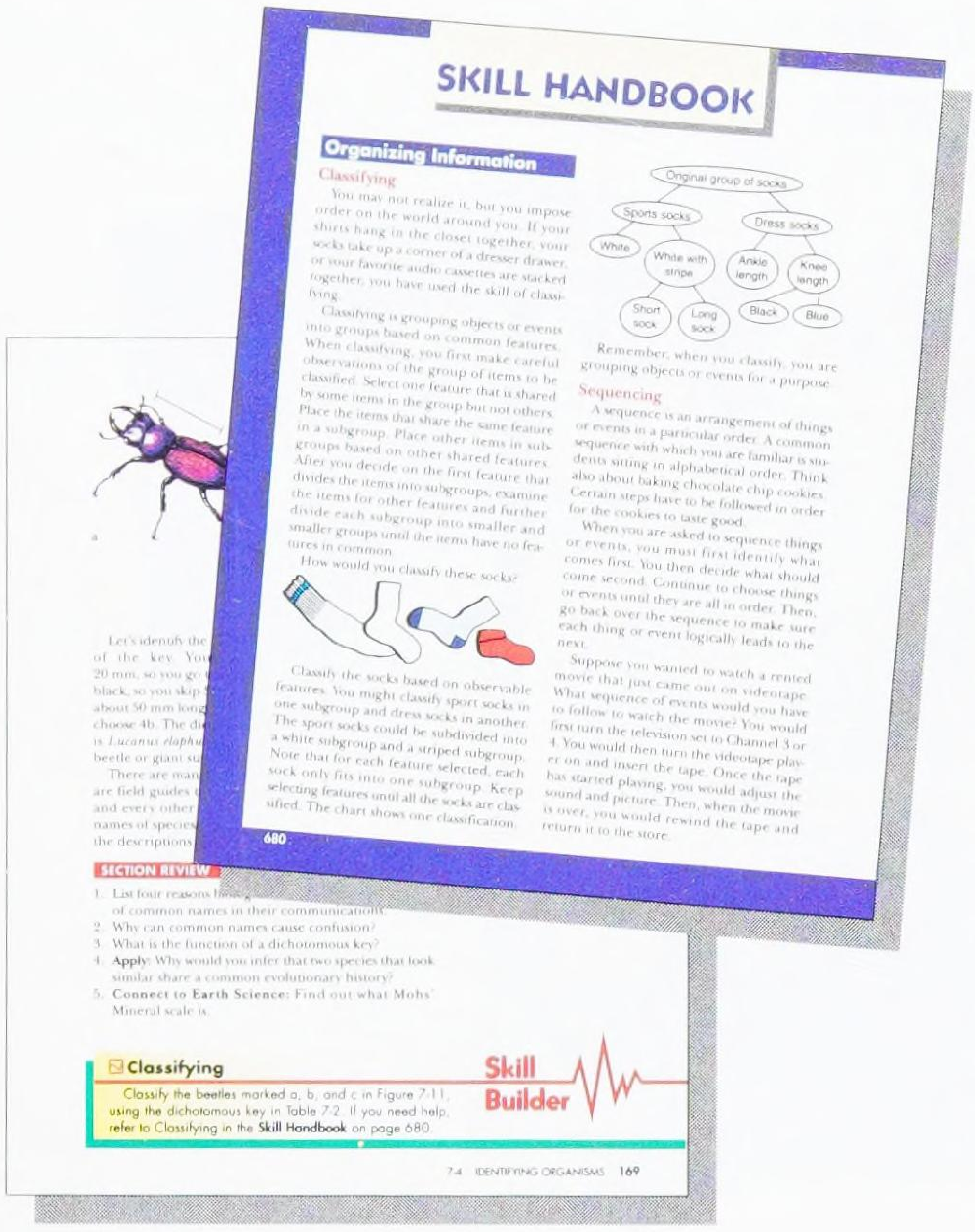


Connect to... Earth Science

Soil is a mixture of weathered rock and decaying organic matter (plant and animal). What roles do pioneer species such as lichens, mosses, and liverworts play in building soil?

All sciences are related. **Connect to...** features allow you to relate the life science topics you are studying to chemistry, physics, and earth science. Use a dictionary or basic library reference to find the answers to these questions.

Discover that you can apply what you've learned as you answer questions and practice your science skills.



SKILL HANDBOOK

Organizing Information

Classifying

You may not realize it, but you impose order on the world around you. If your shirts hang in the closet together, your socks take up a corner of a dresser drawer, or your favorite audio cassettes are stacked together, you have used the skill of classifying.

Classifying is grouping objects or events into groups based on common features. When classifying, you first make careful observations of the group of items to be classified. Select one feature that is shared by some items in the group but not others. Place the items that share the same feature in a subgroup. Place other items in subgroups based on other shared features. After you decide on the first feature that divides the items into subgroups, examine the items for other features and further divide each subgroup into smaller and smaller groups until the items have no features in common.

How would you classify these socks?

Classify the socks based on observable features. You might classify sport socks in one subgroup and dress socks in another. The sport socks could be subdivided into a white subgroup and a striped subgroup. Note that for each feature selected, each sock only fits into one subgroup. Keep selecting features until all the socks are classified. The chart shows one classification.

Remember, when you classify, you are grouping objects or events for a purpose.

Sequencing

A sequence is an arrangement of things or events in a particular order. A common sequence with which you are familiar is students sitting in alphabetical order. Think also about baking chocolate chip cookies. Certain steps have to be followed in order for the cookies to taste good.

When you are asked to sequence things or events, you must first identify what comes first. You then decide what should come second. Continue to choose things or events until they are all in order. Then, go back over the sequence to make sure each thing or event logically leads to the next.

Suppose you wanted to watch a rented movie that just came out on videotape. What sequence of events would you have to follow to watch the movie? You would first turn the television set to Channel 3 or 4. You would then turn the videotape player on and insert the tape. Once the tape has started playing, you would adjust the sound and picture. Then, when the movie is over, you would rewind the tape and return it to the store.

680

Let's identify the
of the key. You
20 mm, so you go
black, so you skip
about 50 mm long
choose 4b. The di
is *Lucanus elaphu*
beetle or giant st

There are man
are field guides
and every other
names of species
the descriptions

SECTION REVIEW

1. List four reasons
of common names in their communications.
2. Why can common names cause confusion?
3. What is the function of a dichotomous key?
4. **Apply:** Why would you infer that two species that look similar share a common evolutionary history?
5. **Connect to Earth Science:** Find out what Mohs' Mineral scale is.

Classifying

Classify the beetles marked a, b, and c in Figure 7-11, using the dichotomous key in Table 7-2. If you need help, refer to Classifying in the **Skill Handbook** on page 680.

Skill Builder

7-4 IDENTIFYING ORGANISMS 169

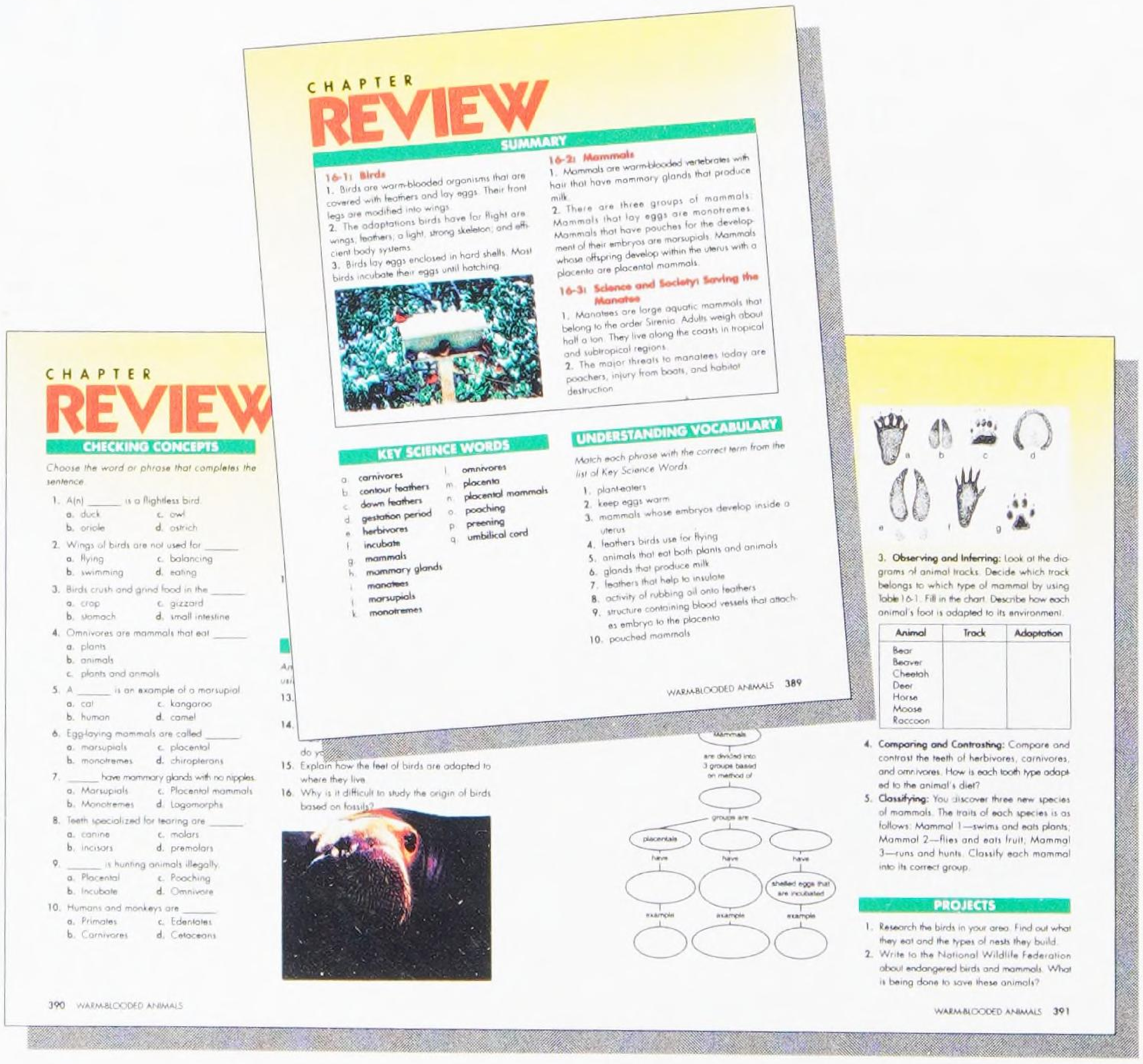
At the end of each section are several Section Review questions that help you test your knowledge. The last question challenges you to think critically and **Apply** what you've learned.

The **Skill Builder** feature lets you sharpen your science skills using only paper and pencil. If you need help with these skills, refer to the **Skill Handbook** at the back of the book. Here, you can find complete information about each type of skill covered in the Skill Builders.

In Your JOURNAL

In your Journal, write about Barbara McClintock and her work with genes that change position on chromosomes. What organism did she use? How did she make her discovery?

In Your Journal features enable you to write expressively about life science topics you are studying. It includes writing creatively, giving reports, writing letters, and forming opinions. You may also keep lab notes and responses to Chapter Review questions in your Journal.



CHAPTER REVIEW

SUMMARY

16-1: Birds

1. Birds are warm-blooded organisms that are covered with feathers and lay eggs. Their front legs are modified into wings.
2. The adaptations birds have for flight are wings; feathers; a light, strong skeleton; and efficient body systems.
3. Birds lay eggs enclosed in hard shells. Most birds incubate their eggs until hatching.

16-2: Mammals

1. Mammals are warm-blooded vertebrates with hair that have mammary glands that produce milk.
2. There are three groups of mammals. Mammals that lay eggs are monotremes. Mammals that have pouches for the development of their embryos are marsupials. Mammals whose offspring develop within the uterus with a placenta are placental mammals.

16-3: Science and Society: Saving the Manatee

1. Manatees are large aquatic mammals that belong to the order Sirenia. Adults weigh about half a ton. They live along the coasts in tropical and subtropical regions.
2. The major threats to manatees today are poachers, injury from boats, and habitat destruction.

KEY SCIENCE WORDS

a. carnivores
b. contour feathers
c. down feathers
d. gestation period
e. herbivores
f. incubate
g. mammals
h. mammary glands
i. manatees
j. marsupials
k. monotremes
l. omnivores
m. placenta
n. placental mammals
o. poaching
p. preening
q. umbilical cord

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. plant-eaters
2. keep eggs warm
3. mammals whose embryos develop inside a uterus
4. feathers birds use for flying
5. animals that eat both plants and animals
6. glands that produce milk
7. feathers that help to insulate
8. activity of rubbing oil onto feathers
9. structure containing blood vessels that attaches embryo to the placenta
10. pouched mammals

WARM-BLOODED ANIMALS 389

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. A(n) ______ is a flightless bird.
a. duck c. owl
b. oriole d. ostrich
2. Wings of birds are not used for ______.
a. flying c. balancing
b. swimming d. eating
3. Birds crush and grind food in the ______.
a. crop c. gizzard
b. stomach d. small intestine
4. Omnivores are mammals that eat ______.
a. plants
b. animals
c. plants and animals
5. A ______ is an example of a marsupial.
a. cat c. kangaroo
b. human d. camel
6. Egg-laying mammals are called ______.
a. marsupials c. placental
b. monotremes d. chiropterans
7. ______ have mammary glands with no nipples.
a. Marsupials c. Placental mammals
b. Monotremes d. Lagomorphs
8. Teeth specialized for tearing are ______.
a. canine c. molars
b. incisors d. premolars
9. ______ is hunting animals illegally.
a. Placental c. Poaching
b. Incubate d. Omnivore
10. Humans and monkeys are ______.
a. Primates c. Edentates
b. Carnivores d. Cetaceans

390 WARM-BLOODED ANIMALS

13.
14.
do yo
15. Explain how the feet of birds are adapted to where they live.
16. Why is it difficult to study the origin of birds based on fossils?

Mammals
are divided into 3 groups based on method of
groups are
placentals
have
shelled eggs that are incubated
example
a
b
c
d
e
f
g

3. **Observing and Inferring:** Look at the diagrams of animal tracks. Decide which track belongs to which type of mammal by using Table 16-1. Fill in the chart. Describe how each animal's foot is adapted to its environment.

Animal	Track	Adaptation
Bear		
Beaver		
Cheetah		
Deer		
Horse		
Moose		
Raccoon		

4. **Comparing and Contrasting:** Compare and contrast the teeth of herbivores, carnivores, and omnivores. How is each tooth type adapted to the animal's diet?
5. **Classifying:** You discover three new species of mammals. The traits of each species is as follows: Mammal 1—swims and eats plants; Mammal 2—flies and eats fruit; Mammal 3—runs and hunts. Classify each mammal into its correct group.

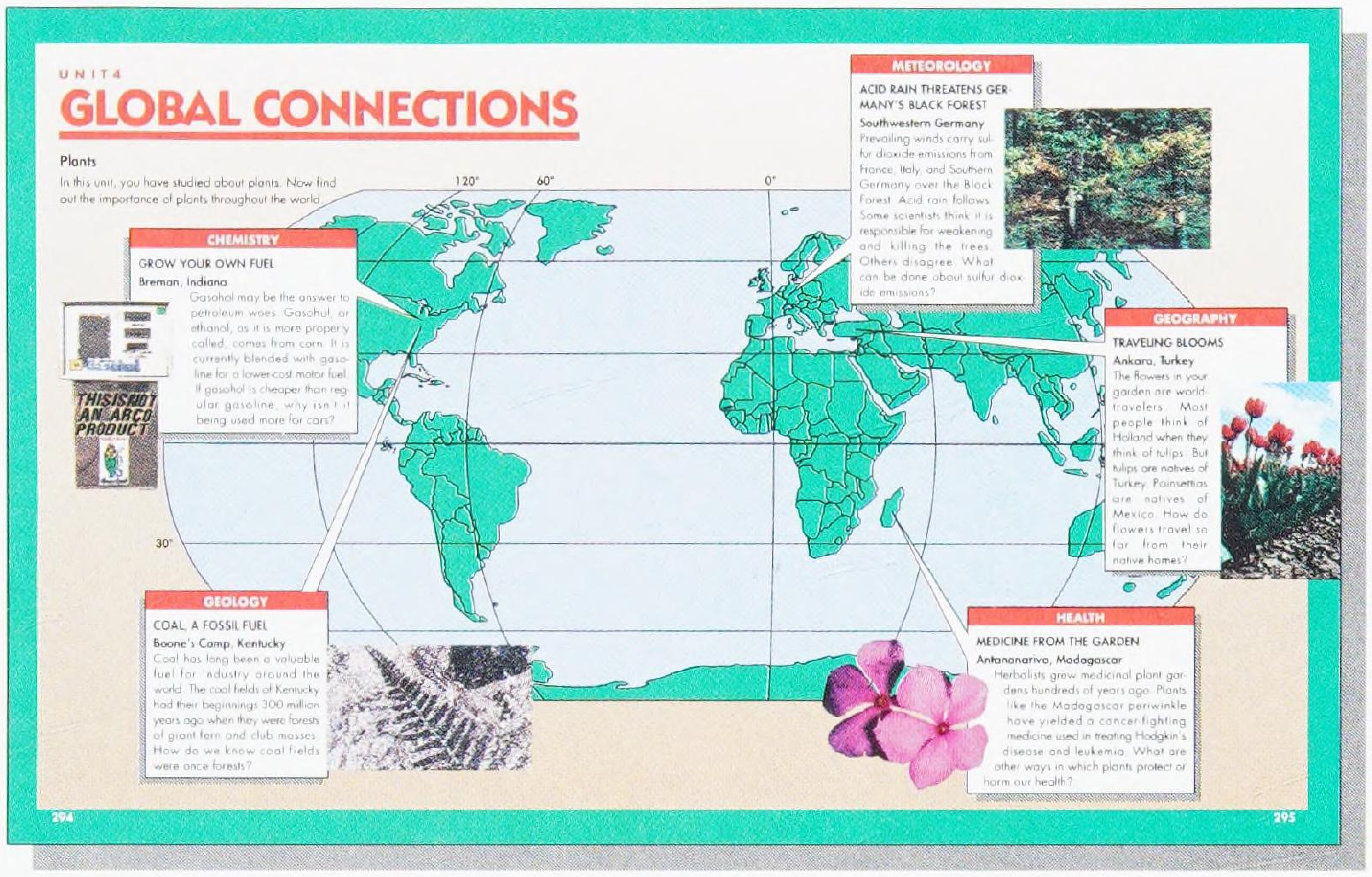
PROJECTS

1. Research the birds in your area. Find out what they eat and the types of nests they build.
2. Write to the National Wildlife Federation about endangered birds and mammals. What is being done to save these animals?

WARM-BLOODED ANIMALS 391

The **Chapter Review** starts with a summary so you can review the major concepts from each section. Then, you'll apply your knowledge and practice thinking skills as you answer the questions that follow. USING LAB SKILLS will help you practice your laboratory techniques.

Discover how life science topics relate to people and places all over the world.



UNIT 4

GLOBAL CONNECTIONS

Plants

In this unit, you have studied about plants. Now find out the importance of plants throughout the world.

CHEMISTRY

GROW YOUR OWN FUEL

Breman, Indiana

Gasohol may be the answer to petroleum woes. Gasohol, or ethanol, as it is more properly called, comes from corn. It is currently blended with gasoline for a lower-cost motor fuel. If gasohol is cheaper than regular gasoline, why isn't it being used more for cars?

GEOLOGY

COAL, A FOSSIL FUEL

Boone's Camp, Kentucky

Coal has long been a valuable fuel for industry around the world. The coal fields of Kentucky had their beginnings 300 million years ago when they were forests of giant fern and club mosses. How do we know coal fields were once forests?

METEOROLOGY

ACID RAIN THREATENS GERMANY'S BLACK FOREST

Southwestern Germany

Prevailing winds carry sulfur dioxide emissions from France, Italy, and Southern Germany over the Black Forest. Acid rain follows. Some scientists think it is responsible for weakening and killing the trees. Others disagree. What can be done about sulfur dioxide emissions?

GEOGRAPHY

TRAVELING BLOOMS

Ankara, Turkey

The flowers in your garden are world travelers. Most people think of Holland when they think of tulips. But tulips are natives of Turkey. Poinsettias are natives of Mexico. How do flowers travel so far from their native homes?

HEALTH

MEDICINE FROM THE GARDEN

Antananarivo, Madagascar

Herbalists grew medicinal plant gardens hundreds of years ago. Plants like the Madagascar periwinkle have yielded a cancer-fighting medicine used in treating Hodgkin's disease and leukemia. What are other ways in which plants protect or harm our health?

294

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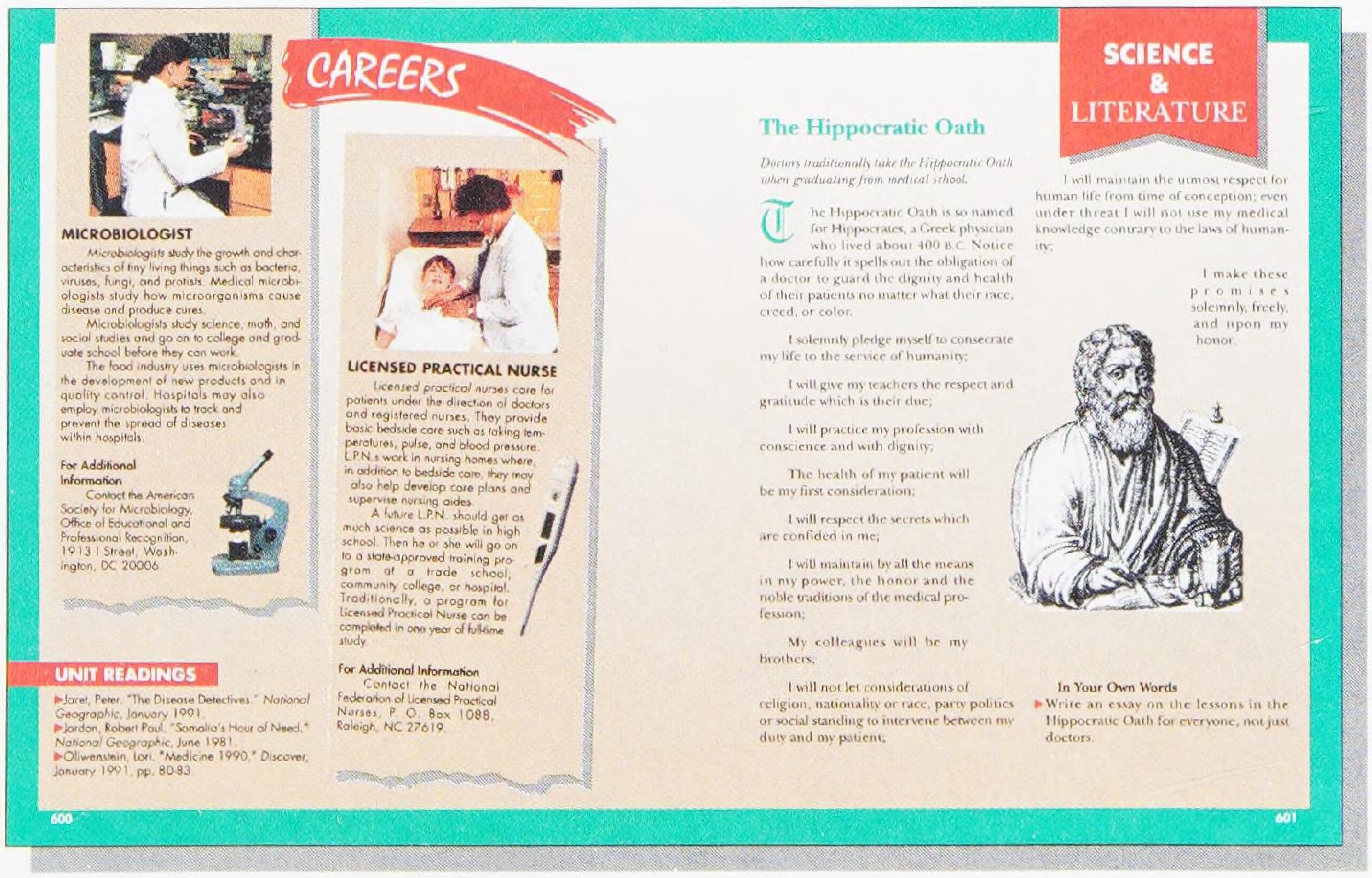
Global Connections help you to see how life science is related to other sciences as well as social studies, history and health.

Also at the end of each unit you will find two **Careers** that describe jobs that relate to the material in the unit you just read. What kind of jobs may be related to maintaining health and what do the people that have these jobs do? Read the careers at the end of Unit 7 to find out.



CAREERS

MICROBIOLOGIST

Microbiologists study the growth and characteristics of tiny living things such as bacteria, viruses, fungi, and protists. Medical microbiologists study how microorganisms cause disease and produce cures.

Microbiologists study science, math, and social studies and go on to college and graduate school before they can work.

The food industry uses microbiologists in the development of new products and in quality control. Hospitals may also employ microbiologists to track and prevent the spread of diseases within hospitals.

For Additional Information

Contact the American Society for Microbiology, Office of Educational and Professional Recognition, 1913 I Street, Washington, DC 20006

LICENSED PRACTICAL NURSE

Licensed practical nurses care for patients under the direction of doctors and registered nurses. They provide basic bedside care such as taking temperatures, pulse, and blood pressure. L.P.N.s work in nursing homes where, in addition to bedside care, they may also help develop care plans and supervise nursing aides.

A future L.P.N. should get as much science as possible in high school. Then he or she will go on to a state-approved training program at a trade school, community college, or hospital. Traditionally, a program for Licensed Practical Nurse can be completed in one year of full-time study.

For Additional Information

Contact the National Federation of Licensed Practical Nurses, P. O. Box 1088, Raleigh, NC 27619.

UNIT READINGS

- Jaret, Peter. "The Disease Detectives." *National Geographic*, January 1991.
- Jordon, Robert Paul. "Somalia's Hour of Need." *National Geographic*, June 1981.
- Oliwenstein, Lori. "Medicine 1990," *Discover*, January 1991, pp. 80-83.

SCIENCE & LITERATURE

The Hippocratic Oath

Doctors traditionally take the Hippocratic Oath when graduating from medical school.

The Hippocratic Oath is so named for Hippocrates, a Greek physician who lived about 400 B.C. Notice how carefully it spells out the obligation of a doctor to guard the dignity and health of their patients no matter what their race, creed, or color.

I solemnly pledge myself to consecrate my life to the service of humanity;

I will give my teachers the respect and gratitude which is their due;

I will practice my profession with conscience and with dignity;

The health of my patient will be my first consideration;

I will respect the secrets which are confided in me;

I will maintain by all the means in my power, the honor and the noble traditions of the medical profession;

My colleagues will be my brothers;

I will not let considerations of religion, nationality or race, party politics or social standing to intervene between my duty and my patient;

I will maintain the utmost respect for human life from time of conception; even under threat I will not use my medical knowledge contrary to the laws of humanity;

I make these promises solemnly, freely, and upon my honor.

In Your Own Words

- Write an essay on the lessons in the Hippocratic Oath for everyone, not just doctors.

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What do life science and literature have in common? A lot, as you'll discover when you read the unit close to Unit 7. Each unit is closed with a reading from literature or an example of art that makes a connection with life science.

UNIT 1 LIFE

What's Happening Here?

A lion cub looks up from the feast he shares with a lioness. In his contented state, he is unaware that he is consuming energy, which will build muscle and bone and eventually bring him to the stage of development where he will reproduce. Living things require energy to grow, develop, and reproduce. The amoeba, the one-celled organism in the small photograph, is less dramatic than a lion, but it too, requires energy, which it derives from other organisms. In this unit, you will learn about the characteristics that all living things share.

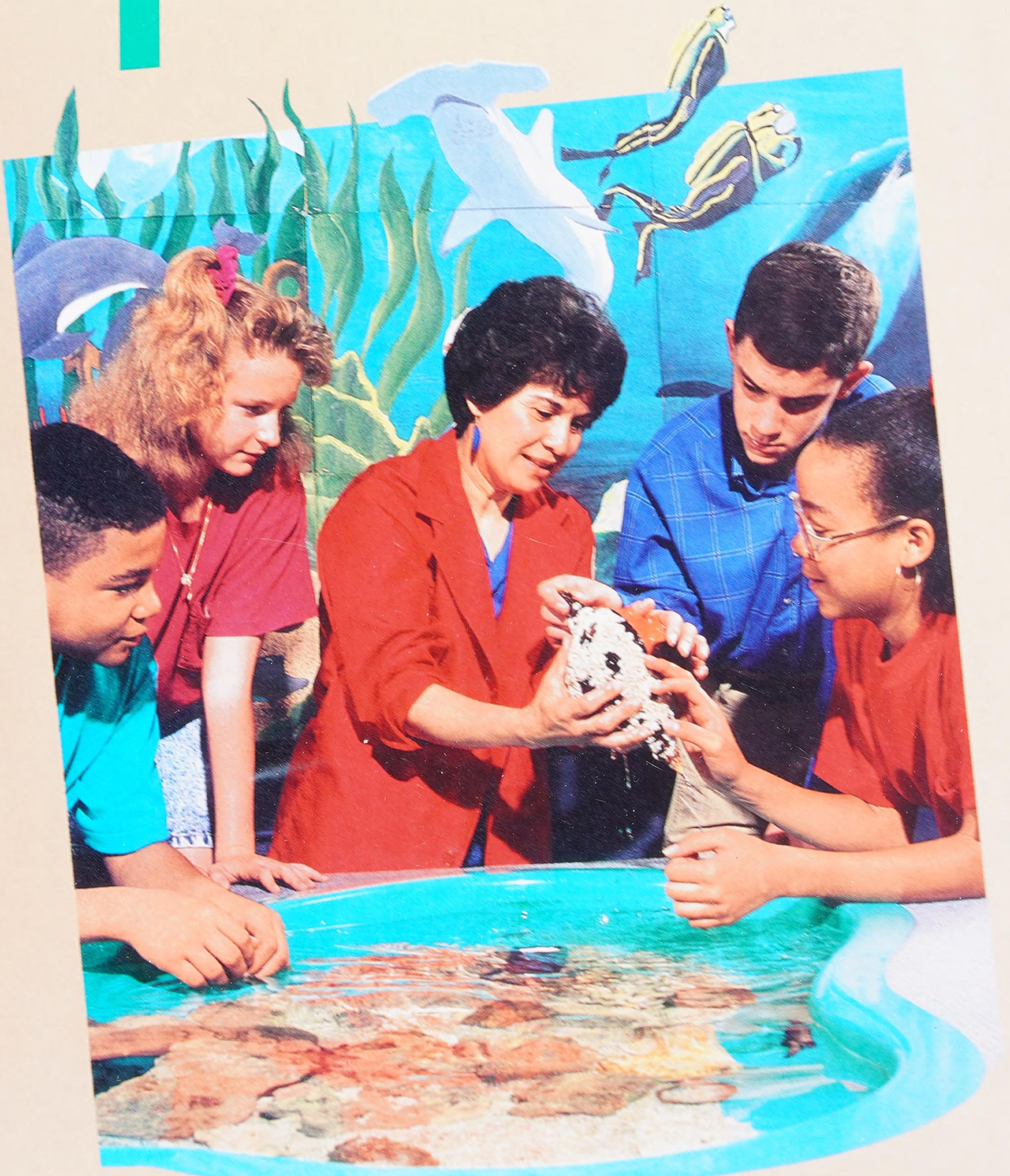
UNIT CONTENTS

Chapter 1 Exploring Life
Chapter 2 The Cell
Chapter 3 Cell Processes
Chapter 4 Cell Reproduction

CHAPTER

1

Exploring Life



Many people think that science is the work of people in white coats who spend hours in a laboratory. But often the work of science begins when someone like yourself notices something new about an ordinary thing, and starts to ask questions.

FIND OUT!

Do this activity to find out about the first steps in scientific research.

Cut a strip of coffee filter paper 3 cm by 12 cm. Using a black felt tip pen, draw a line across the strip of filter about 2 cm from one end. Describe the color of the line. Put 1 cm of water in a small beaker or glass. Hang the filter strip over the beaker so that one end is in the water and the black line is above the water. *Predict* what will happen to the black line. Will you change your original description? If so, how?

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 1-1 Living Things
- Features of Life
- Needs of Living Things

Section 1-2 Where Does Life Come From?
- Life Comes from Life
- Origins

Section 1-3 What Is Science?
- The Work of Science
- Solving Problems
- Theories and Laws
- Critical Thinking
- Measuring in Science
- Safety First

Section 1-4 Science and Society
The Impact of Science on Your Life
- Times Have Changed
- Living with Technology

Previewing Science Skills

- In the **Skill Builders,** you will observe and infer, and measure in SI.
- In the **Activities,** you will Flex Your Brain, hypothesize and observe.
- In the **MINI-Labs,** you will design an experiment and measure in SI.

What's next?

In the Find Out activity, you have had a chance to use scientific methods to test an idea. Now find out about the features of living things and the methods that are used in science to study organisms.

1-1 Living Things

New Science Words

organisms
cells
stimulus
response
homeostasis
development
adaptation
life span

Objectives

- Identify the features of living things in an organism.
- Recognize the needs of living things and explain how these needs are provided.
- Determine that living things and nonliving things interact in the environment.

Features of Life

This book is about life—what it is and how it is maintained. Life is something we may take for granted. Have you ever tried to explain what it means to be alive? Think about life characteristics as you read the following.

Imagine that it's a hot summer day. You can't wait to get out of your hot, stuffy house or apartment. With your dog, you head off to a nearby stream. At first, you practice skipping stones across the water, while the dog runs along the bank barking. Then you sit down on some sand on the bank under a large tree. Dragonflies skim over the water, and the noise of the insects and birds is all you can hear. The dog settles down on the bank under a tree and appears to fall asleep. It sure is great to be alive. But what does this mean? Living things such as you and your dog and the tree are **organisms.** Organisms have certain features that rocks and water don't have. What makes you and your dog different from water and rocks?

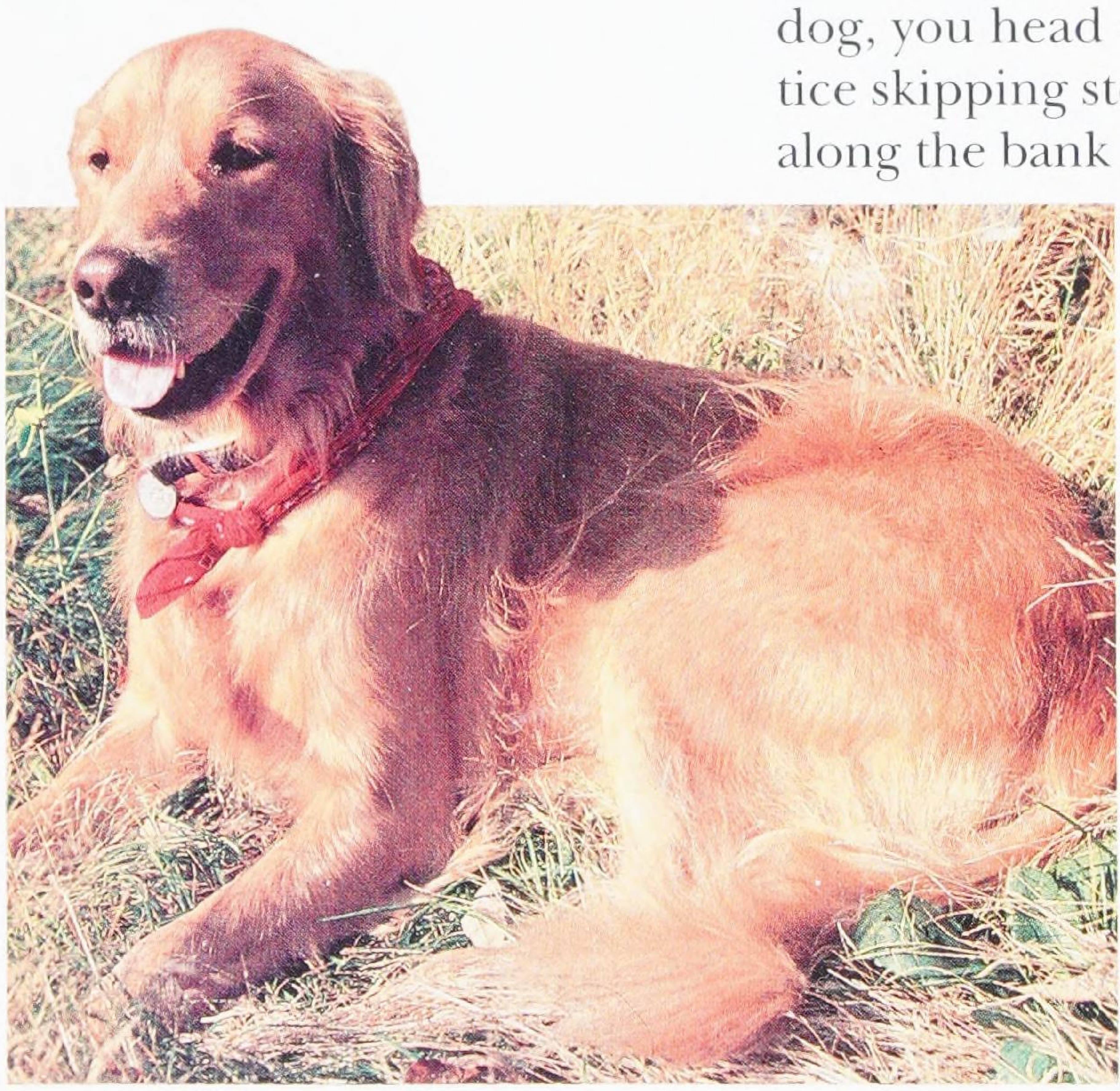


Figure 1-1. Organisms are made of one or more cells, use energy, and respond to their environment. The dog is a many-celled organism.

Organisms are made of one or more cells. You have some things in common with water and rocks in the stream because you are made up of chemicals as they are. However, if someone were to look at you or your dog or the tree under a microscope, it would be clear that each of you is made of units called cells. Water and rocks are not. **Cells** are the smallest units of organisms that carry on the functions of life.

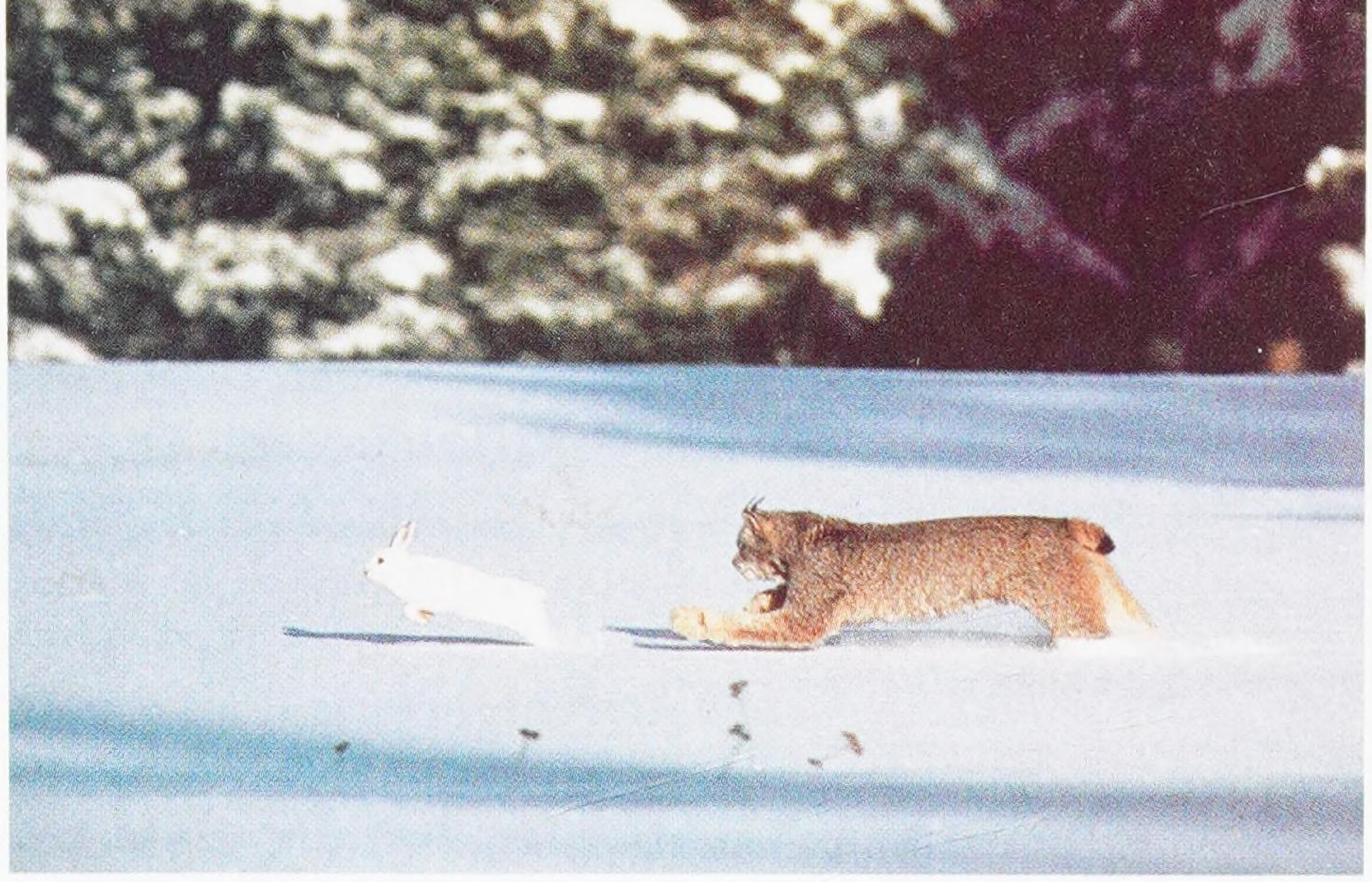


Figure 1-2. Organisms use energy that is supplied by food. For many animals, food is in the form of other animals.

Organisms move. If you ever watch a sleeping dog, it often looks lifeless. Then an ear twitches, or the dog may snore. What about plants? How do they move?

Organisms respond to changes in their environment. Does your dog come running every time it hears a can opener? Anything that an organism responds to, such as sound, is a **stimulus.** The reaction of an organism to a stimulus, in this case probably tail wagging and barking, is a **response.** What other kinds of stimuli can you think of?

Organisms use energy. For organisms to respond to changes in their environment, they need energy. Energy is the ability to make things move or change. It takes energy for your dog to run and bark. It takes energy for you to carry out all the activities you do every day. In the presence of sunlight, plants produce food, which both plants and animals use for energy. Energy is then released from food in a process called respiration.

Organisms adjust to changes in their environment. Think about driving a car. The driver constantly makes small adjustments with the gas pedal to keep the car on the road at a steady rate of speed. The body systems of an organism do something similar. Maintaining steady conditions no matter what is going on inside or outside the organism is called **homeostasis.** Controls in an organism work constantly to bring it back to "normal" after it has been stimulated.

Organisms reproduce. Your dog came from a litter of puppies. You might have looked at its parents to see what it would be like when full grown. Organisms produce new individuals that are usually very like the parent organisms. Oak trees produce acorns that become oak trees. Bluejays lay eggs that develop into young bluejays.

Connect to...

Physics

According to the Law of Conservation of Energy, energy can change form but cannot be created or destroyed under ordinary conditions. In many organisms, chemical energy is converted to mechanical energy. What is the source of chemical energy for animals? In what way do animals show the use of mechanical energy?

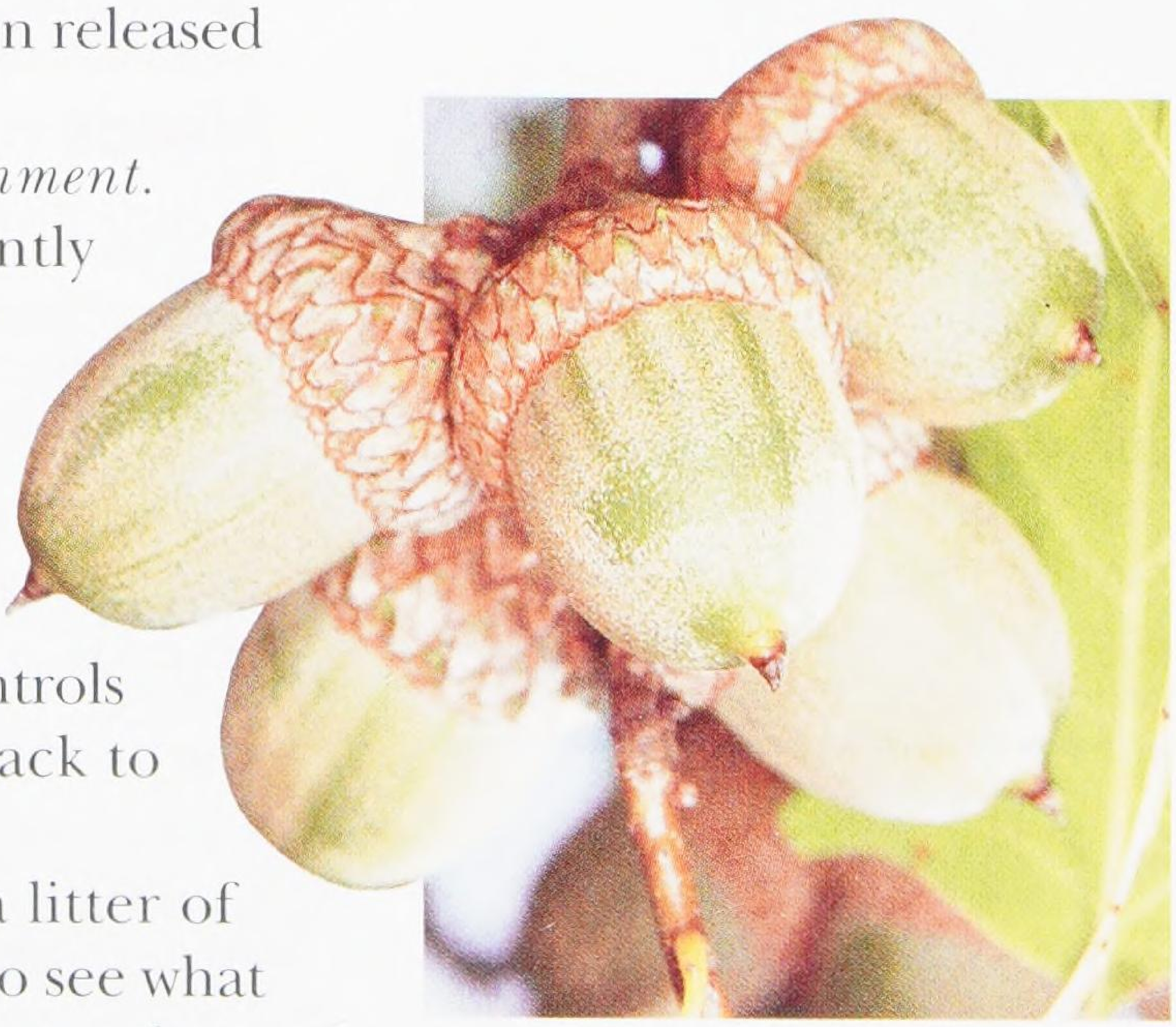


Figure 1-3. Organisms reproduce their own kind.

What is an adaptation?

Organisms grow and develop. When a dog is born, it is very small. With care and feeding, it grows larger. Living things increase in size. They grow. All the changes organisms undergo as they grow are called **development.** Dogs can't see or walk when they are first born. But in eight or nine days, their eyes open, and their legs become strong enough to hold them up. A dog develops into an adult in about two years.

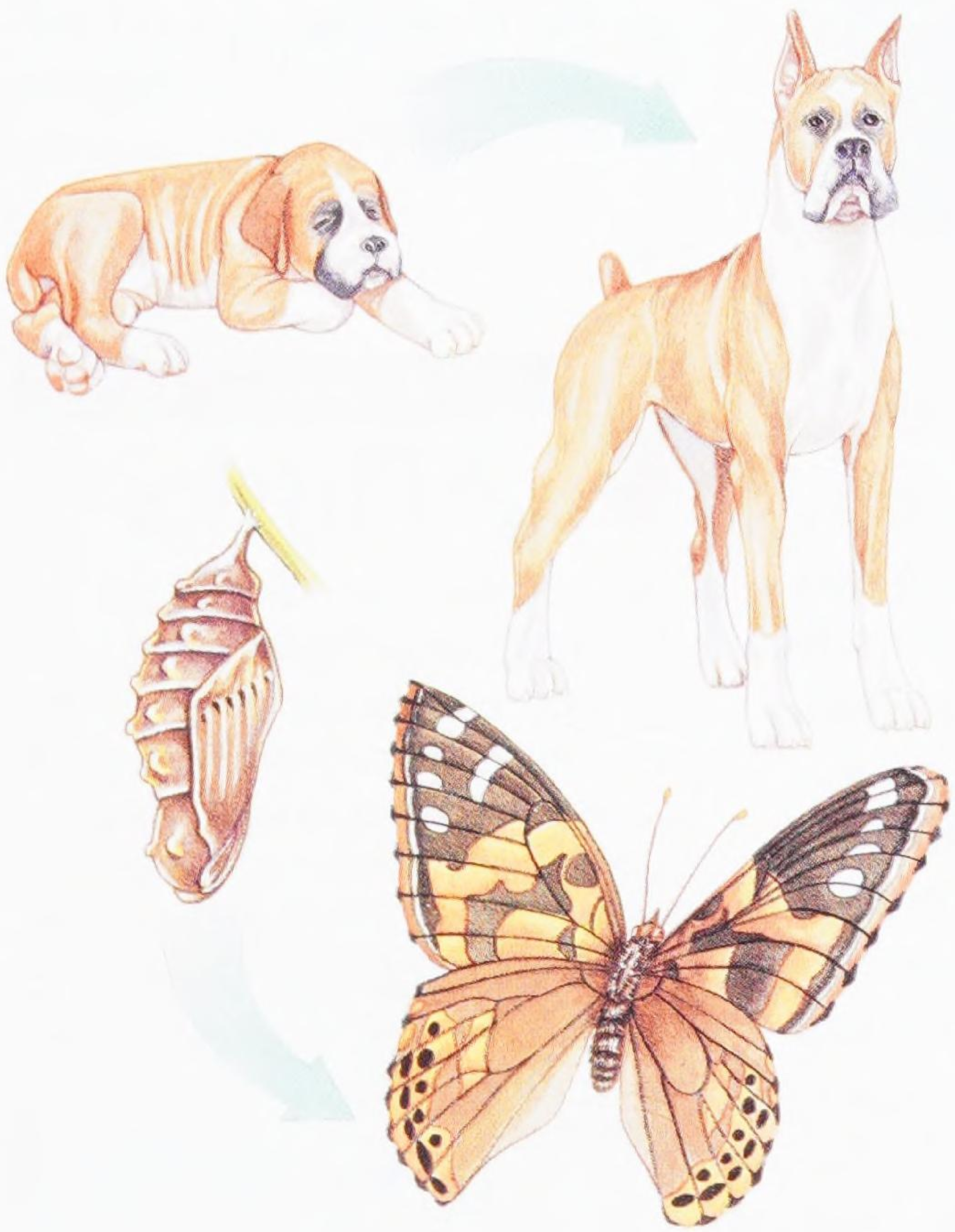


Figure 1-4. As organisms grow and develop, they usually change in appearance.

Organisms adapt. Any characteristic an organism has that makes it better able to survive in its environment is an **adaptation.** Your dog's coat is an adaptation. In summer, the dog sheds hair and his body is cooled. Dogs also pant to release excess body heat. If dogs didn't have these adaptations they would suffer in the summer heat. Plants have adaptations too, such as flower color or hairs. Adaptations are inherited. They are not merely responses the organism makes to an immediate need.

Organisms have life spans. The length of time an organism is expected to live is its **life span.** For some, the life span is very short. Millions of mayflies live only one day, but some bristlecone pine trees have been alive more than 4500 years. Your life span is about 80 years. What is the life span of your dog? How are the needs of living things met during this life span?

In Your JOURNAL

Use library references to find the life span of horses, cows, dogs, cats, shrews, and cockroaches. **In your Journal,** organize this information in a table. Is there any relationship between the size of an organism and its life span?

Needs of Living Things

Sitting on the bank of the stream, you and your dog are probably not aware that you interact with everything else in the environment. However, all organisms take part in many interacting cycles with each other and with all the nonliving things around them. When an organism is part of these relationships, its needs are met.

What are these needs? All organisms need energy and raw materials. The energy that you use comes from food. The main source of energy for living organisms is the sun. Green plants use the sun's energy, along with carbon dioxide, water, and minerals from the soil, to make food in the form of a sugar called glucose. The food is made in green leaves. This process also produces oxygen. Oxygen is used by most organisms to release energy from food.

Raw materials that organisms use are the water, oxygen, and minerals that have been used since life began. Oxygen, water, carbon dioxide, and other chemicals are used, returned to the environment, and used over again.

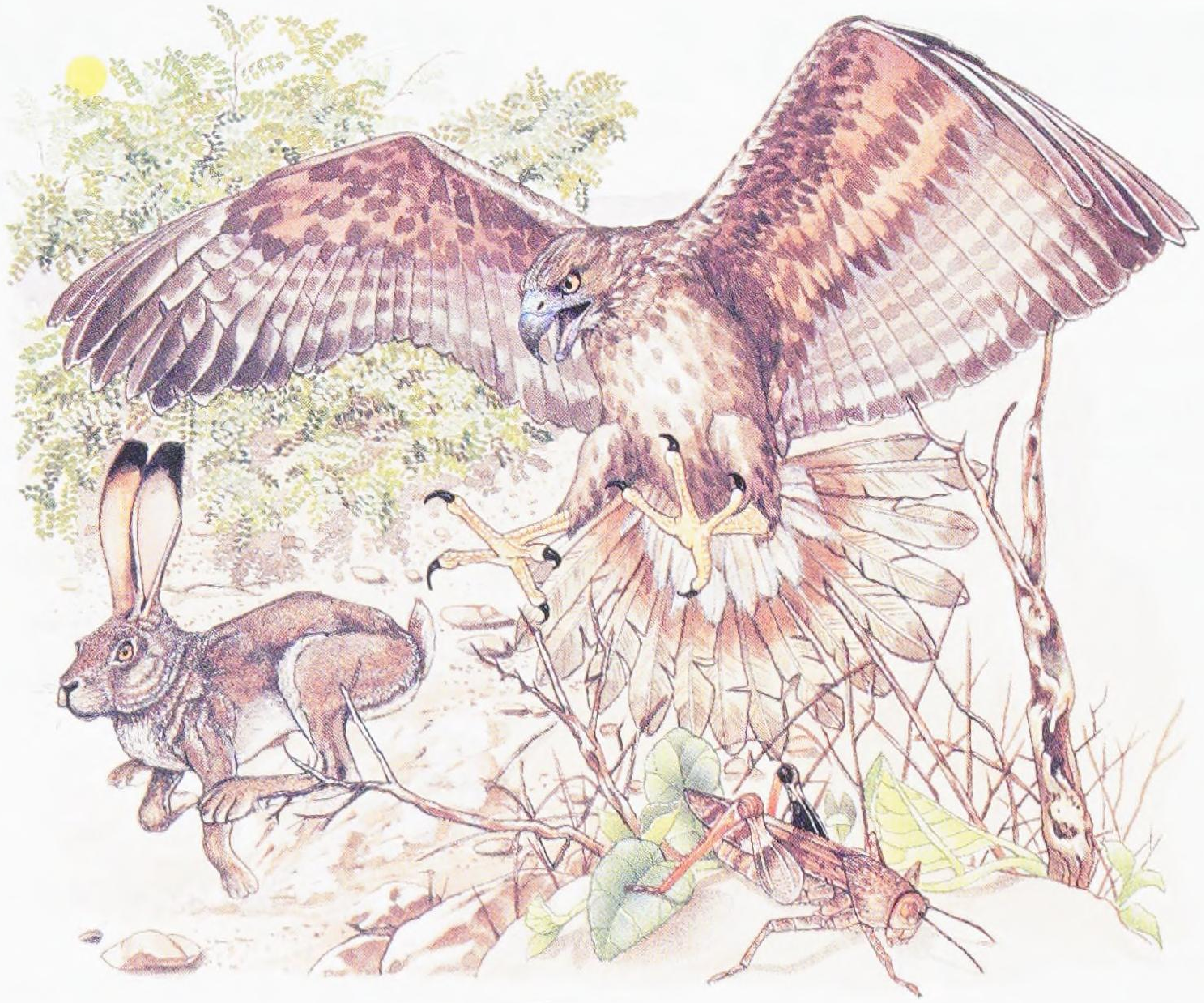


Figure 1-5. In the living world, energy is transferred from one organism to another. Grasshoppers and rabbits feed on plants that have trapped the sun's energy. A hawk obtains energy when it feeds on the rabbit.

Water is especially important. Your dog might live two or three weeks without food, but he would die in a few days without water. Living things are made up of about 70 percent water, and they need to maintain that level. Many substances in nature dissolve in water. Blood and the sap of trees are mostly water. Many organisms are born in or live in water all their lives.

What do organisms need for life?

Are you and your dog different from the water and rocks? To be considered alive, an organism must have certain features. It must be made of cells, use energy, be able to move, respond, adjust, reproduce, grow and develop, and adapt. Organisms need energy, water, and oxygen. Do rocks and water have these properties?

SECTION REVIEW

1. What are the features of organisms?
2. What is the main source of energy used by most organisms?
3. What are the needs of organisms, and how are these needs supplied?
4. **Apply:** Explain how a tree shows the features of life.
5. **Connect to Physics:** Find out how radiant energy (sunlight) and chemical energy (sugar) are related in plants.

Skill Builder

Observing and Inferring

Virus crystals can remain in a jar on a shelf for years. Then once they are put into living cells, they reproduce. Are viruses alive? If you need help, refer to Observing and Inferring in the **Skill Handbook** on page 682.

1-2 Where Does Life Come From?

New Science Words

spontaneous generation
biogenesis

Objectives

- Summarize the results of Redi's and Spallanzani's experiments.
- Explain how Pasteur's experiments disproved the theory of spontaneous generation.
- State the theory of biogenesis.

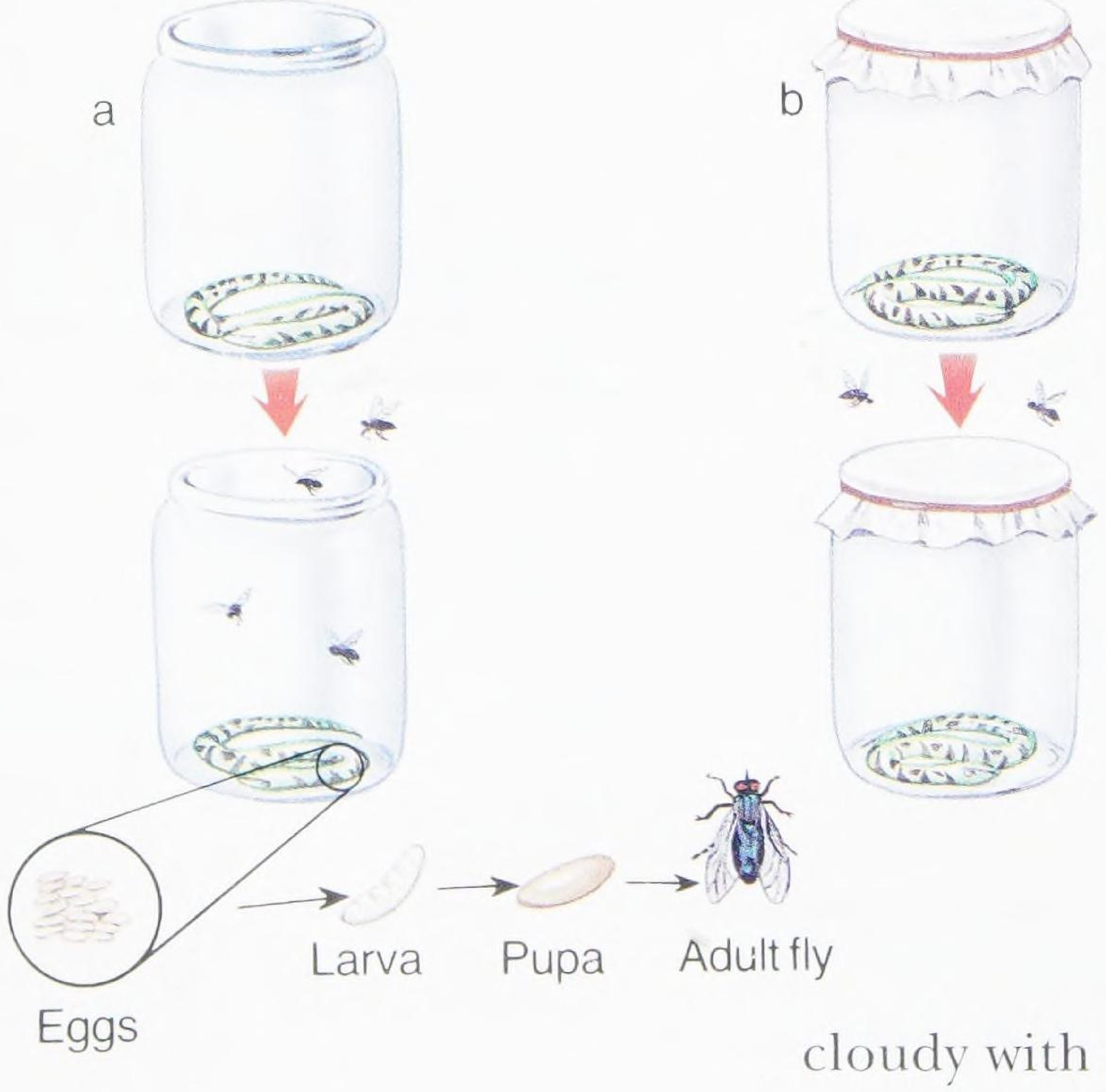
Life Comes from Life

Have you ever walked out after a thunderstorm and found earthworms all over the sidewalk? Earthworms have been found in large numbers after rainstorms for hundreds of years. It's no wonder that people used to think the earthworms had fallen from the sky when it rained. It was a logical conclusion based on repeated experience. But was it true? Jan Baptist van Helmont wrote a recipe for making mice by placing grain in a corner and covering it with rags. For much of history, people believed that living things came from nonliving matter, an idea called the theory of **spontaneous generation.**

People also believed that maggots came from decaying meat. In 1668, Francesco Redi, an Italian doctor, conducted one of the first controlled experiments in science. He showed that maggots hatch from eggs that flies had laid on meat, and not from the meat itself.

In the late 1700s, Lazzaro Spallanzani designed an experiment to show that tiny organisms came from other tiny organisms in the air. He boiled broth in two flasks, sealed one, and left the other one open to the air. The open flask became cloudy with organisms. The sealed flask developed no organisms. People believed Spallanzani had destroyed a "vital force" when he boiled the broth.

Figure 1-6. In Redi's experiment, maggots developed on snake meat that flies could reach (a), but not on meat that was protected from the flies (b).



It was not until the mid-1800s that Louis Pasteur, a French chemist, showed conclusively that living things do not come from nonliving materials. In the experiment illustrated in Figure 1-7, Pasteur boiled broth in flasks with long, curved necks. The broth became contaminated only when dust that had collected in the curved neck of one flask was allowed to mix with the broth. The work of Redi, Spallanzani, Pasteur, and others provided enough evidence finally to disprove the theory of spontaneous generation. It was replaced with **biogenesis,** the theory that living things come only from other living things.

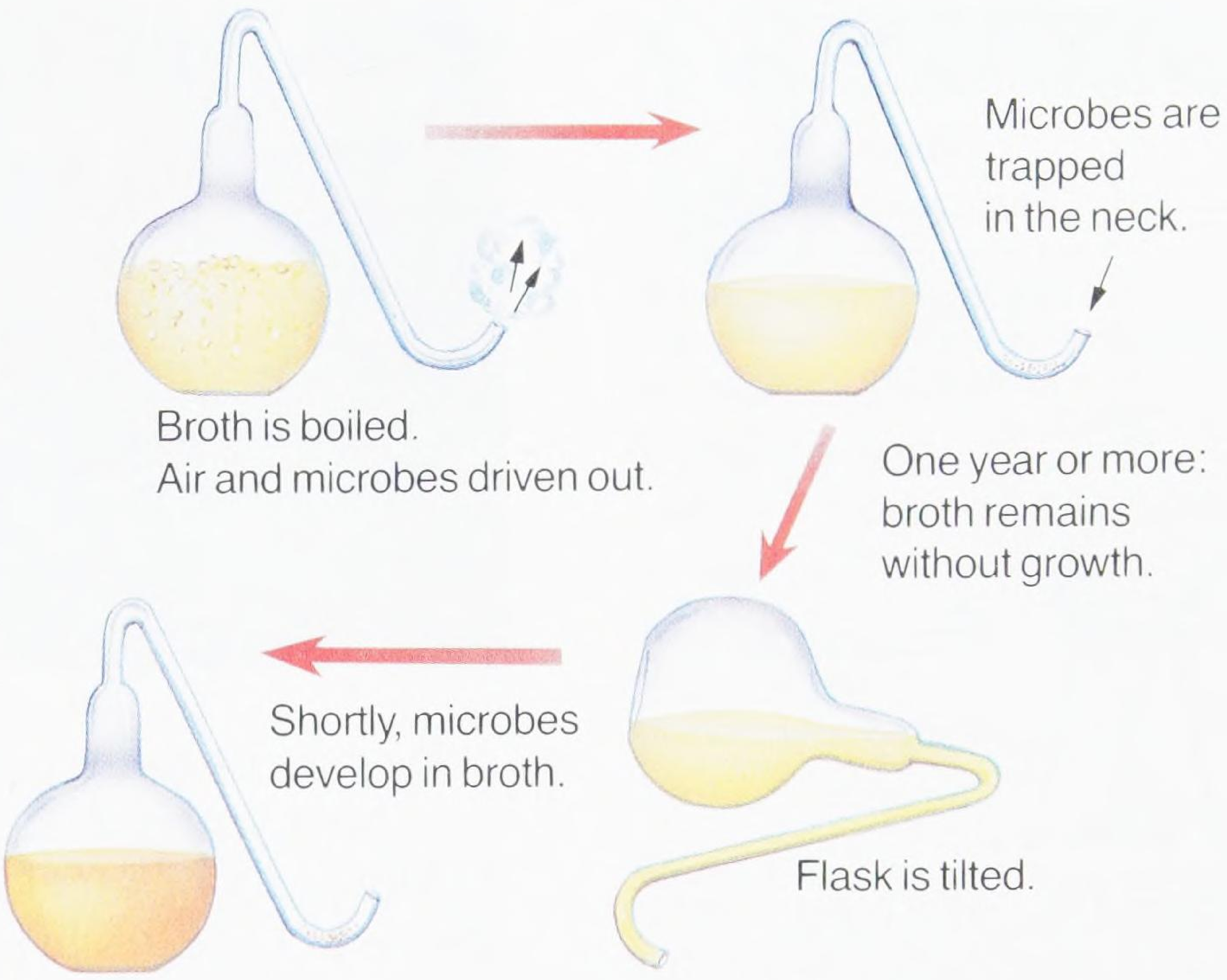

Broth is boiled.
Air and microbes driven out.
Microbes are trapped in the neck.
One year or more: broth remains without growth.
Flask is tilted.
Shortly, microbes develop in broth.

Figure 1-7. Pasteur's experiment disproved the theory of spontaneous generation.

Origins

If living things can come only from other living things, how then did life on Earth begin? Scientists hypothesize that about 5 billion years ago, the solar system was a whirling mass of gas and dust. The sun and planets formed from this mass. Our planet is thought to be about 4.6 billion years old. Rocks found in Australia that are more than 3.5 billion years old contain fossils of once-living organisms.

One hypothesis on the origin of life was proposed by Alexander I. Oparin, a Russian scientist. Oparin suggested that the atmosphere of early Earth was made up of gases similar to ammonia, hydrogen, methane, and water vapor. No free oxygen was present as it is today. Energy from lightning, and ultraviolet rays from the sun, helped these early gases to combine. The gases formed the chemical compounds of which living things are made. Oparin suggested that as the compounds were formed, they fell into hot seas. Over a period of time, the chemical compounds in the seas formed new and more complex compounds. Eventually, the complex compounds were able to copy themselves and make use of other chemicals for energy and food.

Connect to... Earth Science

Scientists hypothesize that Earth's oceans originally formed when water vapor was released into the atmosphere from numerous volcanic eruptions. Once it cooled, rain fell to fill Earth's low areas. Find out what other materials are produced by volcanoes.

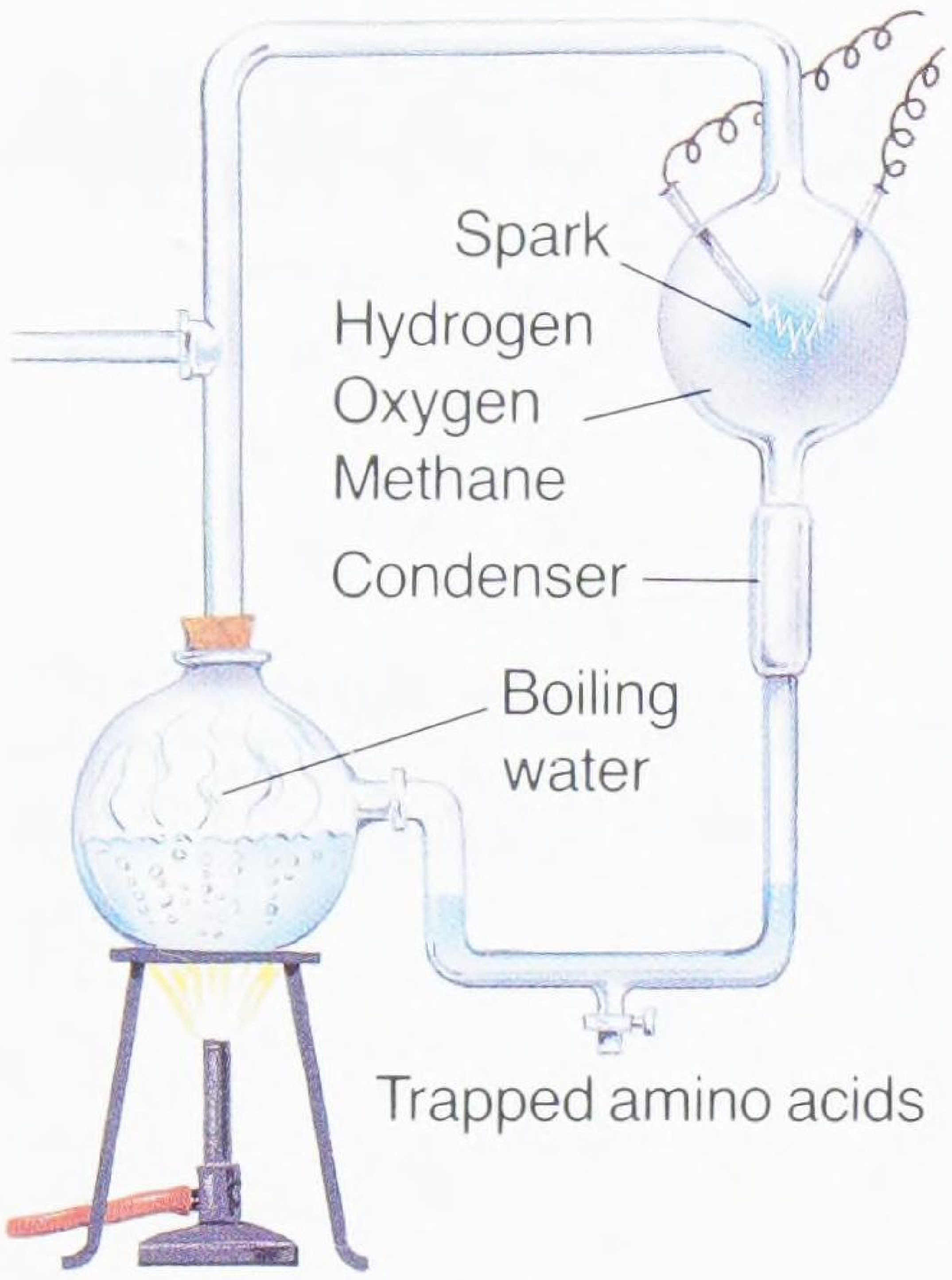


Figure 1-8. Miller's experiment was a model of what many scientists think Earth's early atmosphere was like. Volcanic eruptions like the one to the right remind us of what Earth was probably like while it was in its formative stages.

Ever since Oparin formed his hypothesis, other scientists have been testing it. In 1953, an American scientist, Stanley L. Miller, set up an experiment using the chemicals suggested in Oparin's hypothesis. Electrical sparks were sent through the mixture of chemicals. At the end of a week, new substances, similar to amino acids that are found in all living things, had formed. This showed that substances present in living things *could* come from nonliving materials in the environment. It did not prove that life was formed in this way.

Evidence suggests that life was formed from nonliving matter sometime between 4.6 billion and 3.5 billion years ago. However, scientists are still investigating where the first life came from.

SECTION REVIEW

1. Compare the theory of spontaneous generation with the theory of biogenesis.
2. What was most important about Redi's and Spallanzani's experiments?
3. **Apply:** Explain how it is possible for some of Pasteur's flasks to be uncontaminated after 100 years.
4. **Connect to Earth Science:** Find out the difference between magma and lava.

Skill Builder

Observing and Inferring

People believed that Spallanzani had destroyed some "vital force" in the broth. Did he? Based on the experiment, what could they have inferred about where organisms come from? If you need help, refer to Observing and Inferring in the **Skill Handbook** on page 682.

What Is Science? 1-3

Objectives

- Describe methods scientists use to solve problems.
- Identify and use the SI units of length, volume, mass, and temperature.

New Science Words

scientific methods
hypothesis
variable
control
theory
law

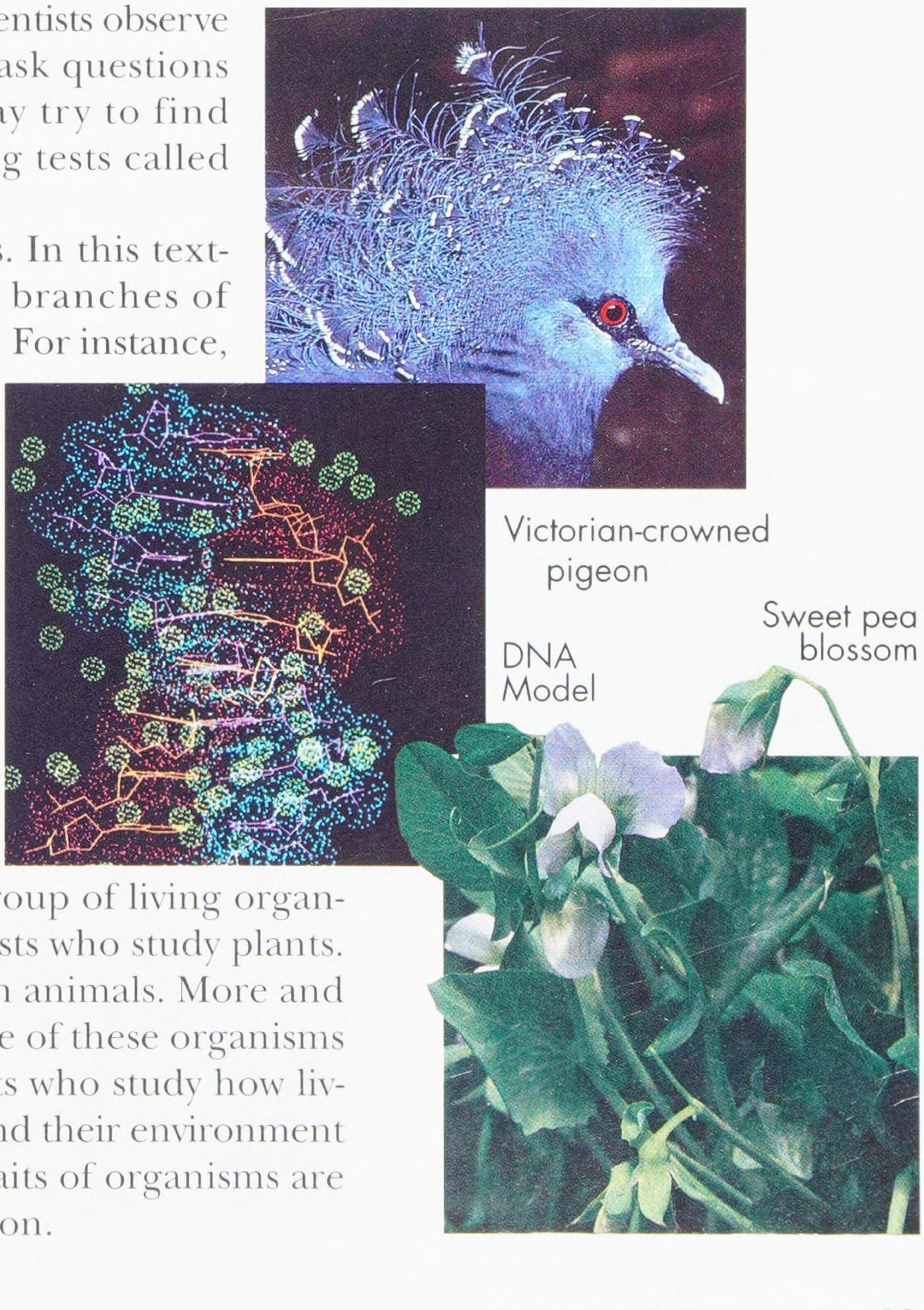
The Work of Science

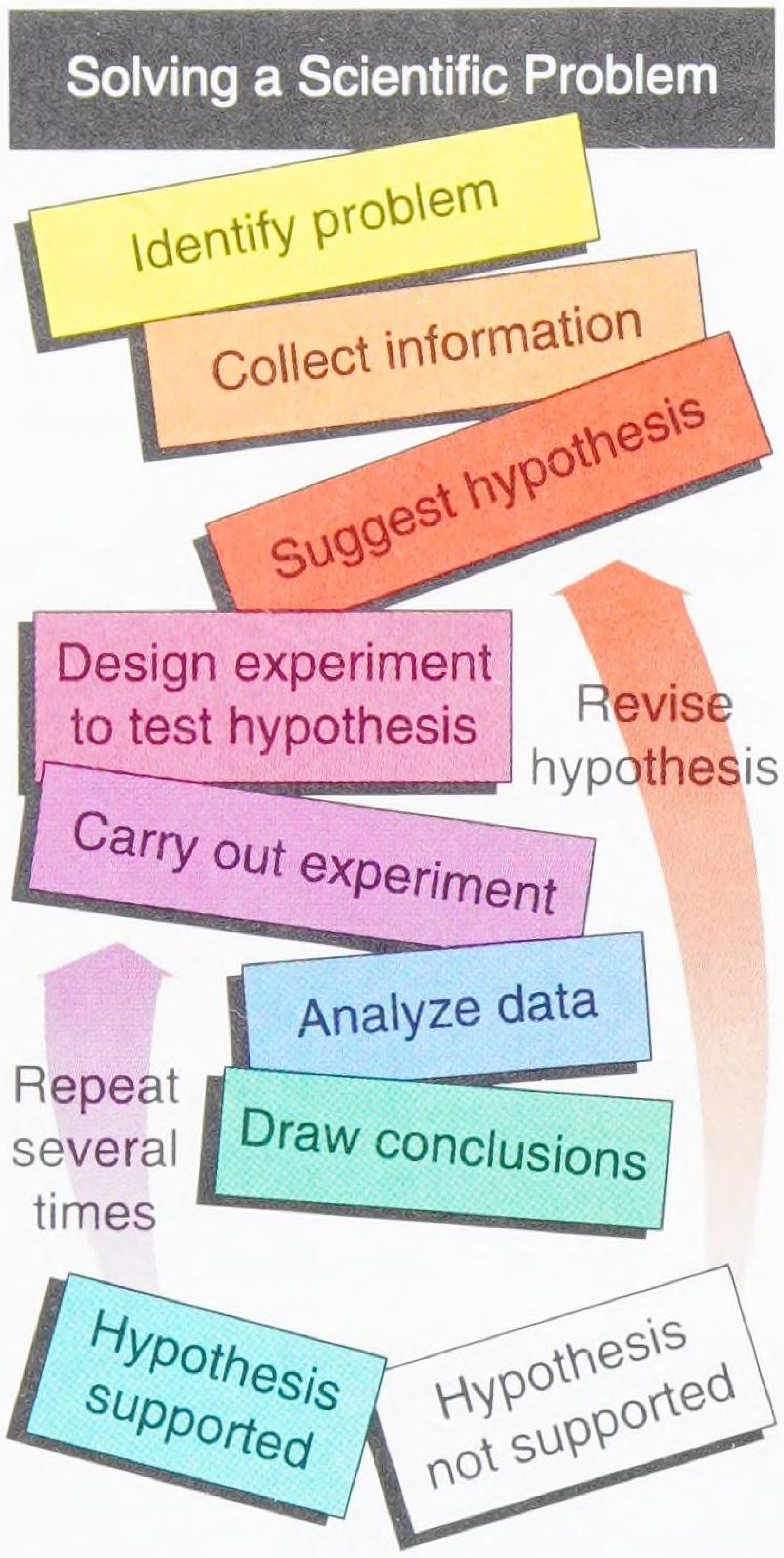
Where do the fleas on your dog come from? Have you ever tried to figure out how to get rid of them? Why do some trees lose their leaves in the fall and others in spring? If you have questions about the world in which you live, you think like a scientist. Scientists observe what goes on around them. They ask questions about their observations and may try to find answers to their questions by using tests called experiments.

Life scientists study living things. In this textbook, you'll be exposed to many branches of science as they touch on life science. For instance, you'll learn some basic chemistry, which is the study of the matter of which things are made. In the study of physics, you will learn that matter and energy are related. Earth science, the study of planet Earth, and life science use both chemistry and physics.

With more than 5 million kinds of organisms on Earth, it would be difficult to study every one. Many life scientists work with only one group of living organisms. Some life scientists are botanists who study plants. Others are zoologists who work with animals. More and more, scientists are seeing that none of these organisms exists alone. Ecologists are scientists who study how living things interact with each other and their environment on Earth. Genetics explains how traits of organisms are passed from generation to generation.

Figure 1-9. In life science, you will study plants and animals, what they are made of, and how they interact with each other.




Solving a Scientific Problem
Identify problem
Collect information
Suggest hypothesis
Design experiment to test hypothesis
Revise hypothesis
Carry out experiment
Analyze data
Repeat several times
Draw conclusions
Hypothesis supported
Hypothesis not supported

What is a hypothesis?

Solving Problems

Do scientists always find answers to their questions? No. Do they always do experiments in laboratories? Not always. There is no set method that all scientists use to solve problems. Each problem is different. Yet, solving any problem requires organization, doesn't it? In science, this organization often takes the form of a series of procedures or **scientific methods.**

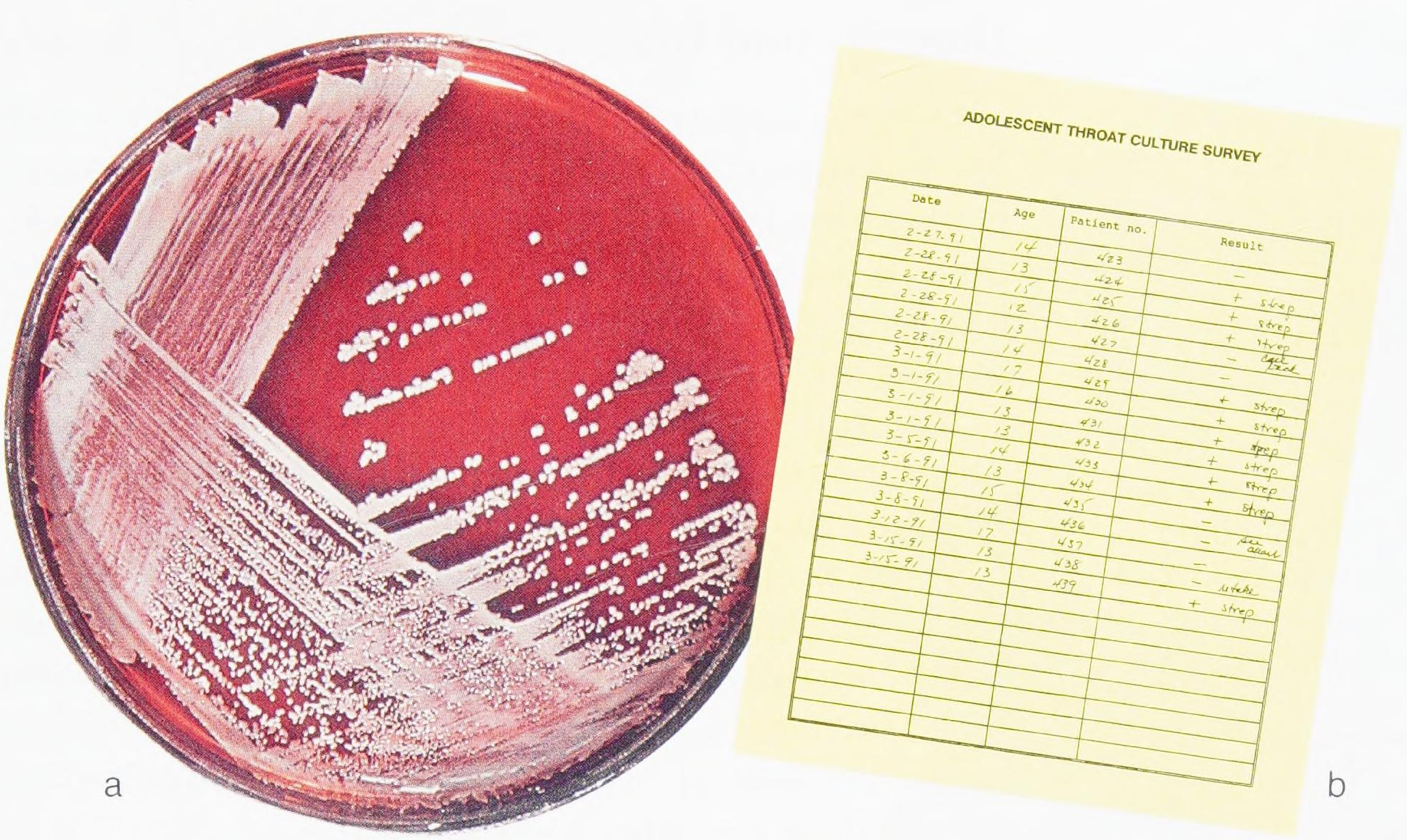
The diagram to the left shows an order in which scientific methods might be used. You begin by observing something that you cannot explain. Suppose you awake one morning with a sore throat. It hurts all day, so you go to the doctor after school. The first step in a scientific method is to *state the problem.* A scientist can't begin to solve a problem until it's clearly stated. You tell the doctor that you have a sore throat.

The second step is to *gather information* about the problem. Tell the doctor everything you've observed about your sore throat—when it began hurting and how it feels now. The doctor makes her own observations. She takes your temperature and examines your throat.

The next step is to *form a hypothesis.* A **hypothesis** is a prediction that can be tested. Based on her experience, the doctor hypothesizes that you have strep throat. She knows she can test her hypothesis right there in her laboratory. A hypothesis always has to be something you can test.

To test her hypothesis the doctor will *perform an experiment.* In an experiment, a series of steps is followed that tests a hypothesis using controlled conditions. The doctor

Figure 1-10. Performing an experiment is an important step in solving a problem scientifically. Here the doctor takes a throat culture to find out whether or not your throat infection is caused by the streptococcus bacterium. The larger photograph shows some streptococcus cells.



ADOLESCENT THROAT CULTURE SURVEY

Date	Age	Patient no.	Result
2-27-91	14	423	–
2-28-91	13	424	+ strep
2-28-91	15	425	+ strep
2-28-91	12	426	+ strep
2-28-91	13	427	– cult back
2-28-91	14	428	–
3-1-91	17	429	+ strep
3-1-91	16	430	+ strep
3-1-91	13	431	+ strep
3-1-91	13	432	+ strep
3-5-91	14	433	+ strep
3-6-91	13	434	+ strep
3-8-91	15	435	–
3-8-91	14	436	– see chart
3-12-91	17	437	–
3-15-91	13	438	– retake
3-15-91	13	439	+ strep

Figure 1-11. Research in life science may involve equipment such as a petri dish (a). Data is a record of observations (b). Data is recorded in a journal.

takes a throat culture from you. She has a petri dish with a growth medium, which she marks "experimental." She gently rubs the surface of the medium in the experimental dish with your throat culture. The dish marked experimental is the variable. A **variable** is the factor tested in an experiment. The doctor also has a sample of the organism that is known to cause strep throat. She will use this sample as a control to compare with your culture. A **control** is the standard used to compare with the outcome of a test.

The doctor may give you a prescription for some capsules that will relieve your symptoms. She tells you that she will call you in 24 hours with the test results. The next day, a lab technician identifies the growth in the experimental petri dish. This *data is recorded* in your chart. The doctor uses the data to draw her conclusions. A *conclusion* is a logical answer to a question based on data and observations of the test materials.

The next step in the search for an answer is to *accept or reject the hypothesis*. When you return, the doctor tells you that the growth in the experimental dish shows that your sore throat was caused by another kind of bacterium. You don't have strep throat. She has had to reject her original hypothesis.

The last step in solving a problem scientifically is to *do something with the results*. Your doctor may use the data in a paper she is preparing on different kinds of sore throats found in adolescents. She may have begun to notice some common factors in her data.

MINI-Lab

What is an experiment?

Using the information that you have just learned about scientific methods, **design an experiment** to find out how much water can be absorbed by different brands of disposable diapers. Work in groups to form a **hypothesis** and plan your experiment. Discuss your plan with your teacher. Plan to include as many scientific methods as you can, identify each method, and then perform the experiment. You will need to refer to Experimentation Skills in the **Skill Handbook** on pages 684–687.

Theories and Laws

Observations and conclusions in science either develop or support existing information. A **theory** is an explanation of things or events based on many observations. A theory is not someone's opinion, nor is a theory a vague idea. Hypotheses that have been tested over and over again and cannot be shown to be false support theories. You have already read about the theory of spontaneous generation. Theories can be changed as new data uncover new information.

Large amounts of data in science often show a trend. A scientific **law** based on these repeating data tells us how nature works. A law is a reliable description of nature based on many observations. In life science, you will learn about the laws of heredity. Laws may change as more information becomes known.

Scientific methods help answer questions. Your questions may be as simple as "Where did I leave my house key?" or as complex as "What can we do about air pollution?" Will these methods guarantee that you will get an answer? Not always. Often they just lead you to more questions, but that is the work of science.

Connect to...

Chemistry

In 1859, Robert Cheseborough, a chemist, took samples of an annoying, sticky, waxy material that no one wanted from an oil rig in Titusville, PA. From it, he produced Vaseline. What characteristics of good science did Mr. Cheseborough have?

PROBLEM SOLVING

The Long Island Duck Problem

Dr. Jessie Price is a specialist in veterinary bacteriology, particularly diseases in birds. In the 1950's, while studying for her doctorate at Cornell University, Jessie Price was confronted with a major problem. Large flocks of White Pekin ducks on Long Island were dying from a mysterious illness. Long Island, New York was one of the largest producers of ducks for food in the United States. As many as 10% of these ducks were dying, costing farmers more than $250,000 a year.

It took several years of testing, experimenting, and comparing samples of blood from diseased ducks before Price identified the organism that infected the ducks with a bacterial disease. After six years of research, Price finally found a vaccine that protected new ducklings from infection.

Think Critically: How does Dr. Price's experience with scientific methods compare with the doctor on pages 14 and 15?

Critical Thinking

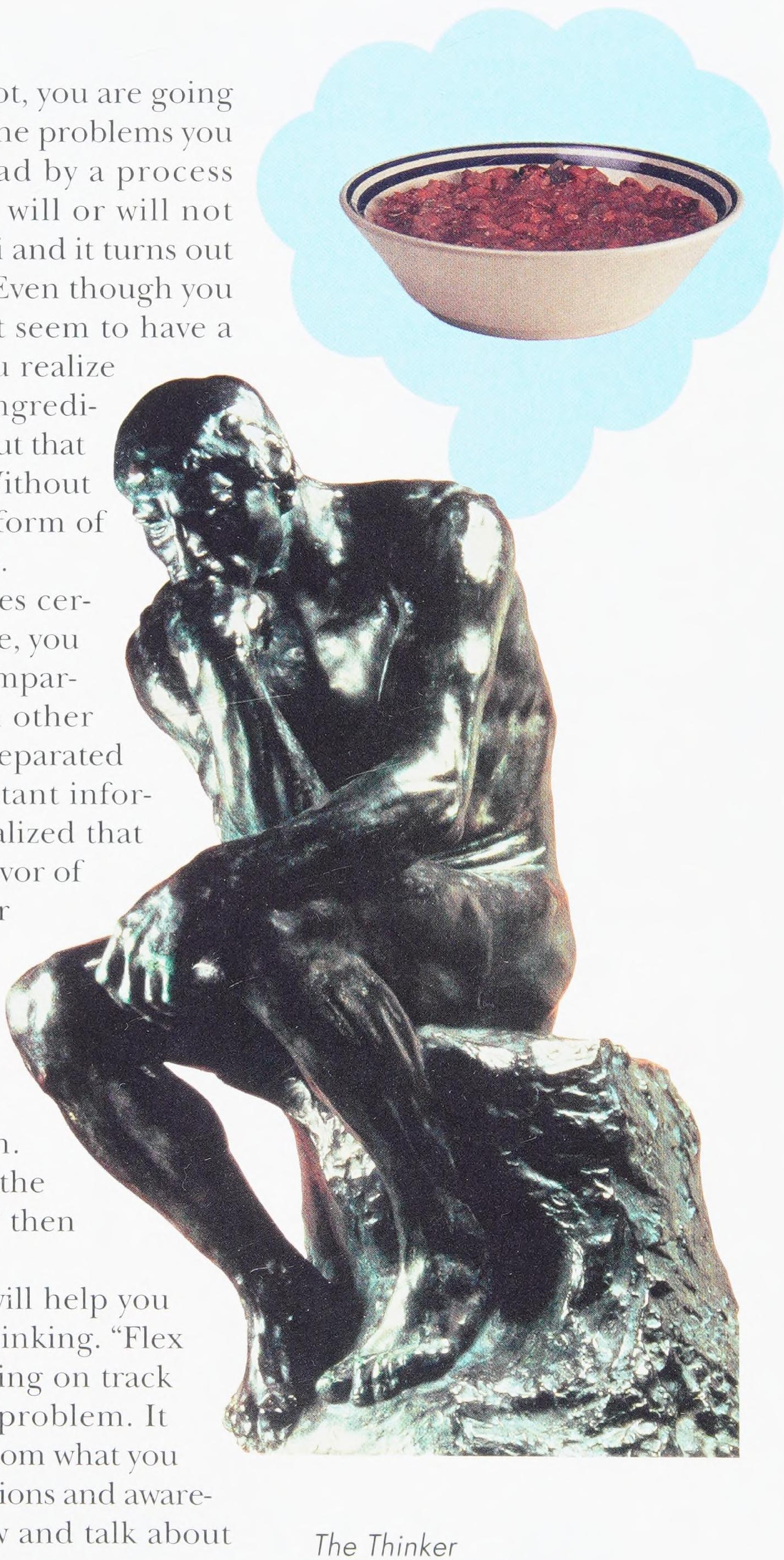
Whether you become a scientist or not, you are going to solve problems all your life. Most of the problems you encounter will be solved in your head by a process of sorting through ideas to see what will or will not work. Suppose you make a batch of chili and it turns out badly. What went wrong with the chili? Even though you followed the usual recipe, it just didn't seem to have a zippy taste. After thinking for a bit, you realize that you left out one very important ingredient—chili powder! How did you figure out that lack of chili powder was the problem? Without being aware of it, you probably used a form of problem solving called critical thinking.

Critical thinking is a process that uses certain skills to solve problems. For example, you identified the problem by mentally comparing the not-so-great batch of chili with other batches of chili you've eaten. First you separated important information from unimportant information. For instance, you may have realized that temperature had little to do with the flavor of the chili. You may have examined your assumption that you followed the recipe correctly. After looking at the recipe again, you concluded that it was chili powder that was missing.

Finally, you probably went one step further and analyzed your conclusion. Would lack of chili powder have made the chili taste blah? If your answer was "yes," then you may have solved the problem.

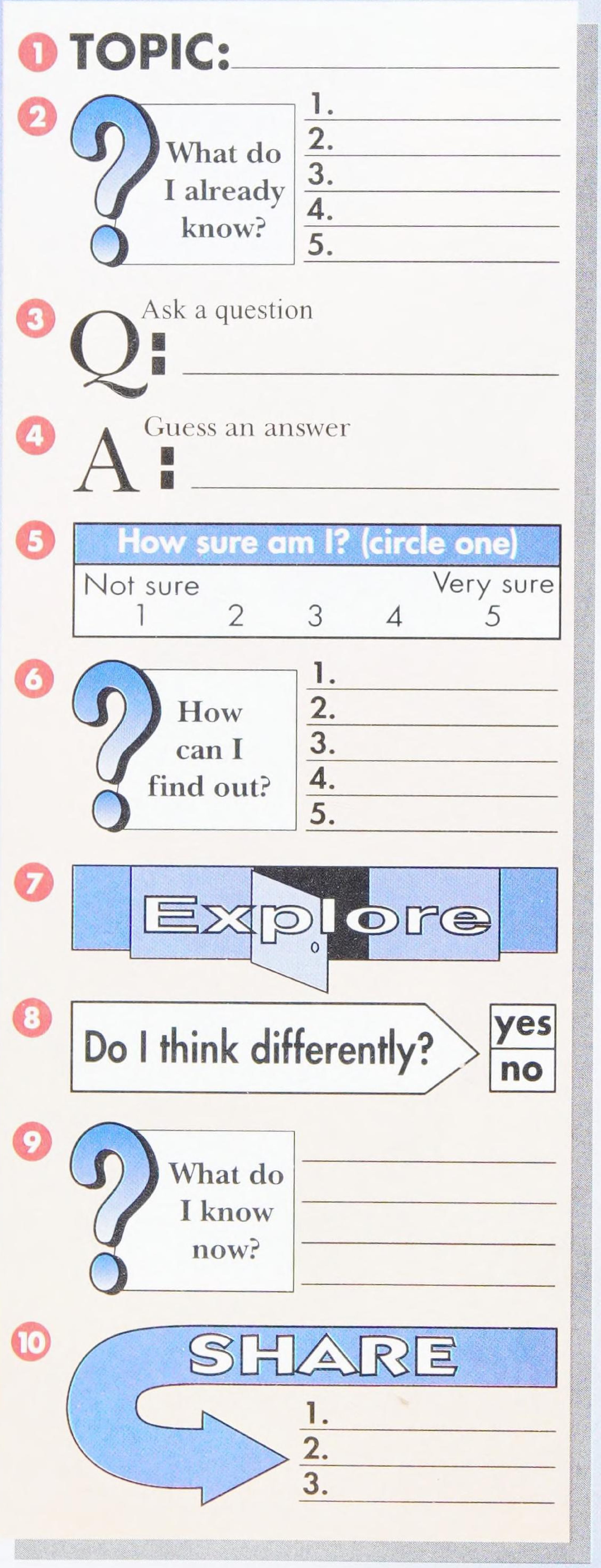
"Flex Your Brain" is an activity that will help you think about and examine your way of thinking. "Flex Your Brain" is a way to keep your thinking on track when you are investigating a topic or problem. It takes you through steps of exploration from what you already know and believe, to new conclusions and awareness. Then, it encourages you to review and talk about the steps you took.

"Flex Your Brain" will help you improve your critical thinking skills. You'll become a better problem solver, and your next batch of chili will taste great. "Flex Your Brain" is found on the next page.



The Thinker
by Auguste Rodin

FLEX Your Brain



① **TOPIC:** ______

② What do I already know?
1. ______
2. ______
3. ______
4. ______
5. ______

③ Ask a question
Q: ______

④ Guess an answer
A: ______

⑤ **How sure am I? (circle one)**
Not sure … Very sure
1 2 3 4 5

⑥ How can I find out?
1. ______
2. ______
3. ______
4. ______
5. ______

⑦ Explore

⑧ Do I think differently? ☐ yes ☐ no

⑨ What do I know now?
______
______
______
______

⑩ SHARE
1. ______
2. ______
3. ______

① Fill in the topic your teacher gives you.

② Jot down what you already know about the topic.

③ Using what you already know (Step 2), form a question about the topic. Are you unsure about one of the items you listed? Do you want to know more? Do you want to know what, how, or why? Write down your question.

④ Guess an answer to your question. In the next few steps, you will be exploring the reasonableness of your answer. Write down your guess.

⑤ Circle the number in the box that matches how sure you are of your answer in Step 4. This is your chance to rate your confidence in what you've done so far and, later, to see how your level of sureness affects your thinking.

⑥ How can you find out more about your topic? You might want to read a book, ask an expert, or do an experiment. Write down ways you can find out more.

⑦ Make a plan to explore your answer. Use the resources you listed in Step 6. Then, carry out your plan.

⑧ Now that you've explored, go back to your answer in Step 4. Would you answer differently? Mark one of the boxes.

⑨ Considering what you learned in your exploration, answer your question again, adding new things you've learned. You may completely change your answer.

⑩ It's important to be able to talk about thinking. Choose three people to tell about how you arrived at your response in every step. For example, don't just read what you wrote down in Step 2. Try to share how you thought of those things.

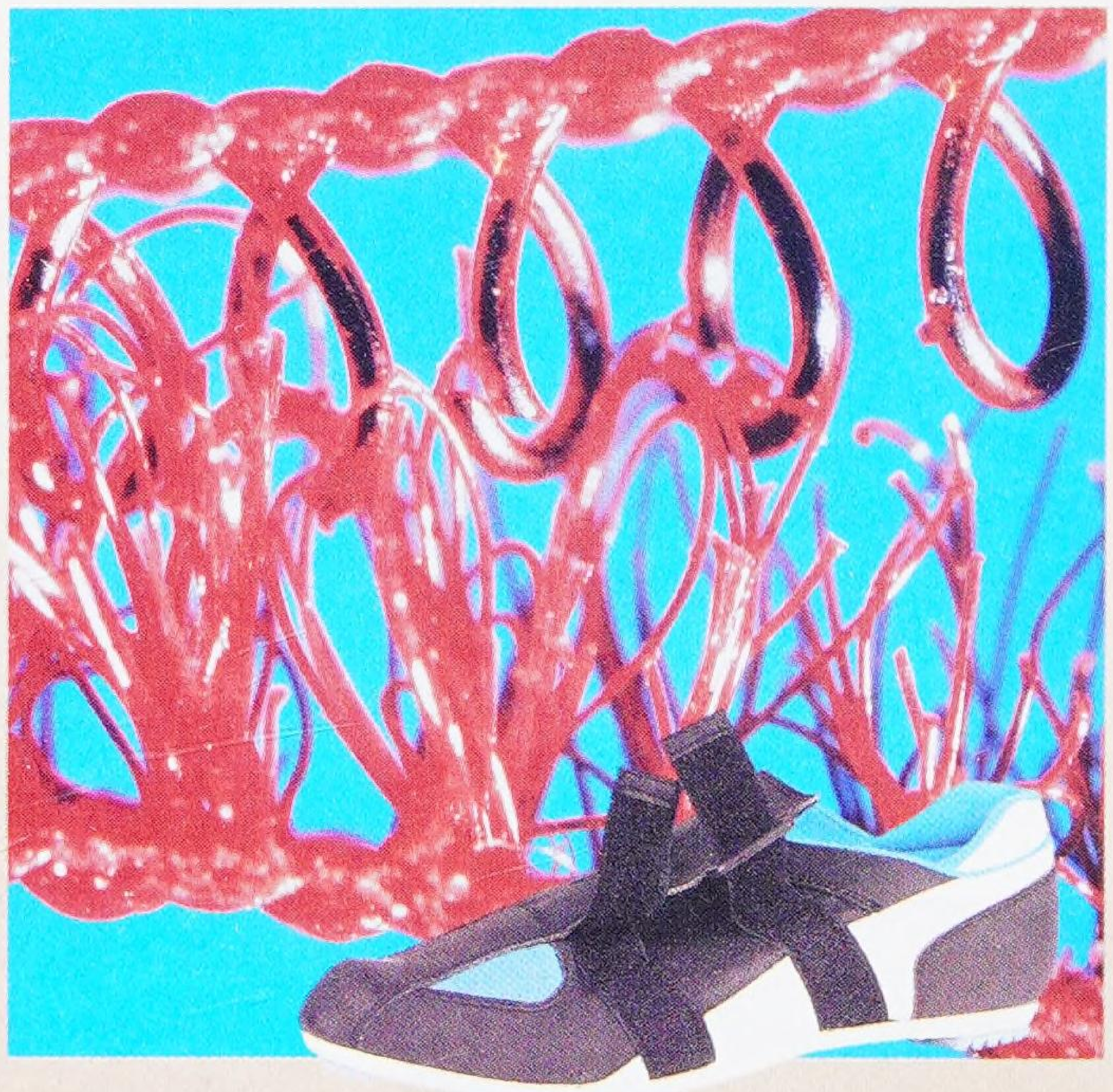
TECHNOLOGY

Cocklebursˌand Space Shuttles

One day a Swiss engineer returned from a walk and became interested in the thistles sticking to his socks. He studied the cockleburs under a microscope and found hundreds of tiny hook and loop structures. As a result of this observation, he invented Velcro.

Nylon filament is woven into loops and coated. Half of the loops are cut to form hooks. Velcro has come to have many uses. It has been used to secure artificial hearts. In the space program, more than 64 500 cm^2 of Velcro tape have been used on each space shuttle. Velcro is also used to strap on blood pressure cuffs, on sneakers, and is found in astronauts' helmets as a nose scratcher.

Think Critically: What does this story tell you about how science works?



Measuring in Science

Think about how many things you use every day that measure or are measured. The thermostat keeps the air in your home at a certain temperature. Meters in your house measure water, electricity, and gas usage. Your food comes in pounds, ounces, and liters, and you step on a scale to check your weight.

Scientists use a system of measurement to make observations. Scientists around the world have agreed to use the International System of Units, or SI. SI is based on certain metric units. Using the same system gives scientists a common language. They can understand each other's research and compare results. Most of the units you will use in this textbook are shown in Table 1-2 on page 20. Because you are used to using the English system of pounds, ounces, and inches, a chart has been included in Appendix B on page 671 to help you convert these units to SI.

Science and READING

What do doctors, dentists, veterinarians, hairdressers, and school nurses have to learn about life science before they are allowed to do their jobs? Find these careers in the United States Government Guide to Careers and record the requirements for each **in your Journal.**

Table 1-1

COMMON METRIC UNITS AND PREFIXES

Length	Mass	Volume	Prefix	Symbol	Meaning
kilometer	kilogram	cubic meter	kilo-	k	1000.0
meter	gram	liter	centi-	c	0.01 (1/100)
centimeter		cubic centimeter	milli-	m	0.001 (1/1000)
millimeter	milligram	milliliter			

SI is based on units of ten. It is easy to use because calculations are made by multiplying or dividing by ten. Prefixes are used with units to change them to larger or smaller units.

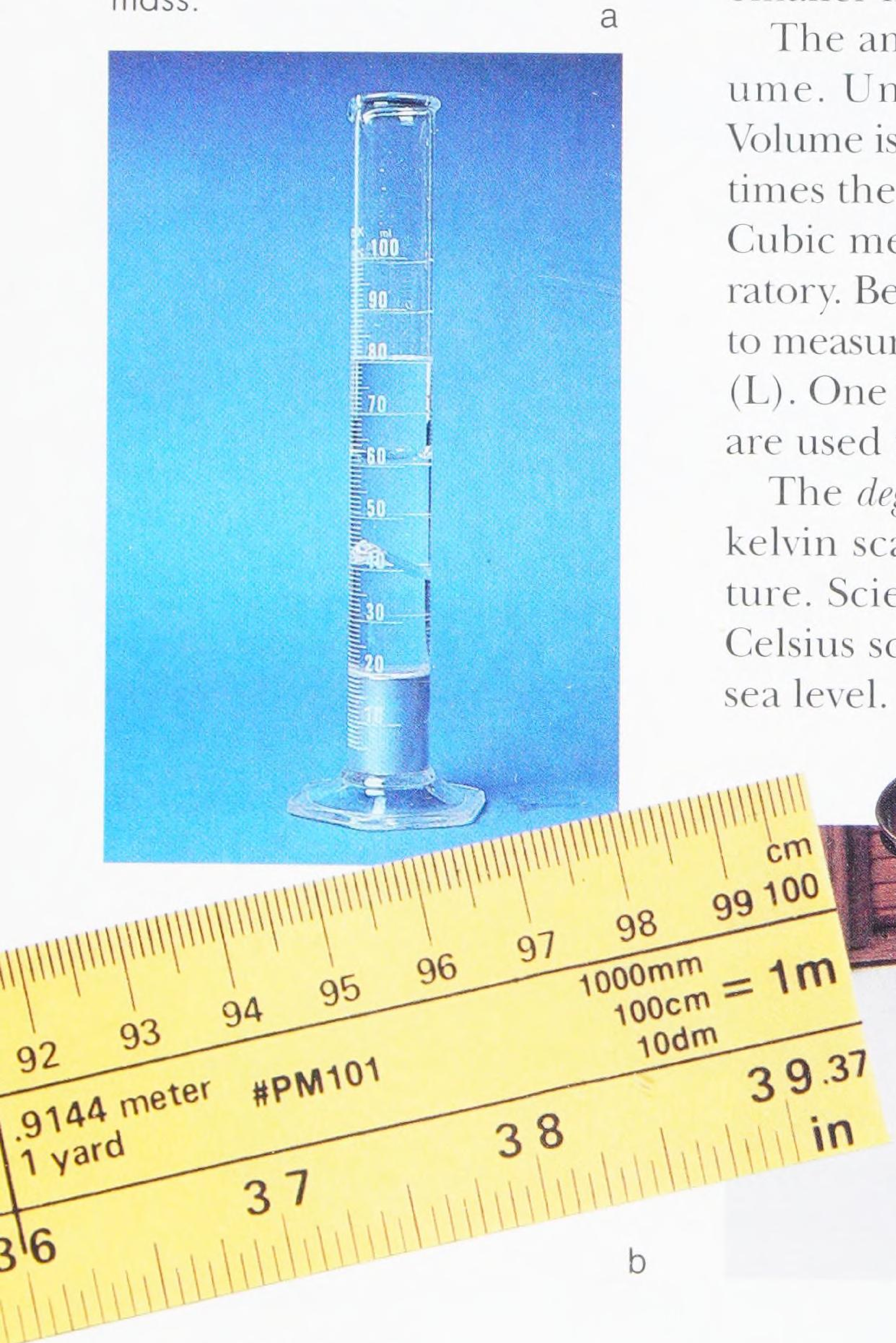
The SI unit of length is the *meter.* A metric ruler or a meterstick is used to measure length. If you look at the table, you see that 1000 meters equal one kilometer. Large distances are measured in kilometers.

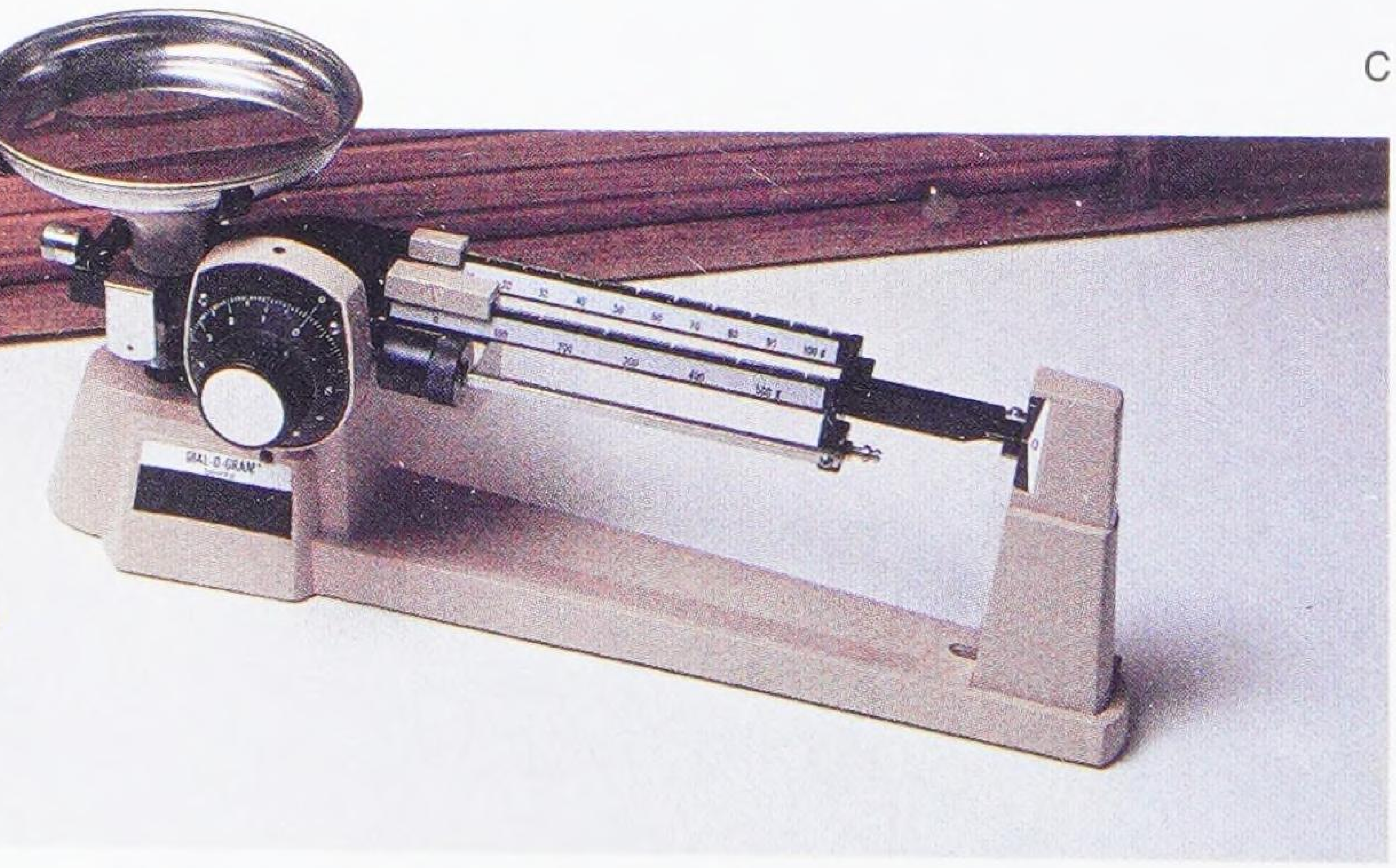
Mass is the amount of matter in an object. Mass is measured with a balance. The SI unit of mass is the *kilogram.* Smaller masses are measured in grams and milligrams.

The amount of space occupied by an object is its volume. Units of volume are based on units of length. Volume is found by multiplying the length times the width times the height. The SI unit of volume is the *cubic meter.* Cubic meters are too large to be of any use in the laboratory. Because of this, the cubic centimeter (cm^3) is used to measure volume. Liquid volumes are measured in liters (L). One liter has the same volume as 1000 cm^3. Milliliters are used to measure smaller volumes.

The *degree* is the unit for measuring temperature. The kelvin scale is the SI standard for measuring temperature. Scientists also often use the Celsius scale. On the Celsius scale, water freezes at 0°C and boils at 100°C at sea level.

Figure 1-12. A graduated cylinder (a) is used to measure volumes. Metric rulers (b) are used to measure lengths. A pan balance (c) is used to measure mass.





You will use these measurements to work in the laboratory this year. Working in the laboratory will help you understand the life science concepts in your textbook. You will observe and conduct experiments. Some of the observations you will make will be the same ones made by students and researchers for years and years. The important thing is that *you* will have seen these things yourself.

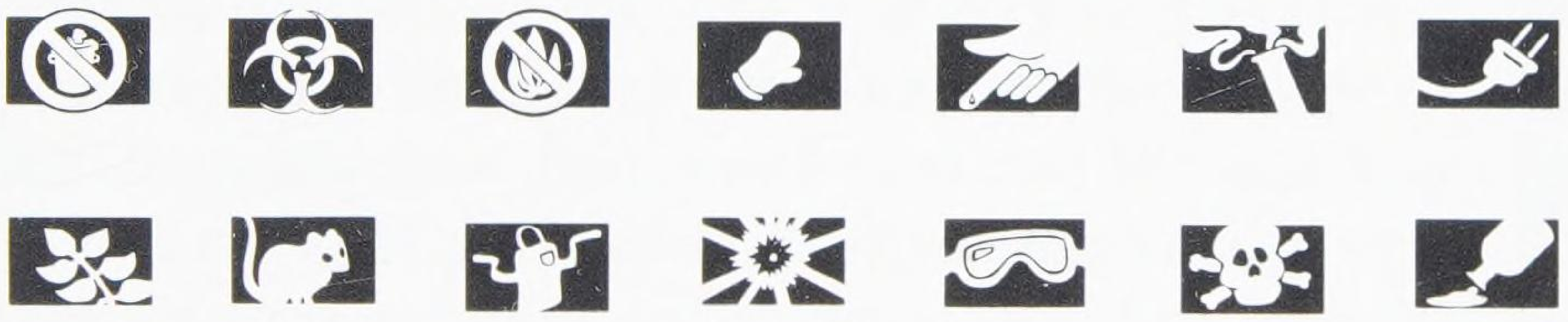
MINI-Lab

How are things measured?

Working in pairs, **measure** the mass of the following items: a small paper clip, small glass of water, a metal spoon, and a rock. Use a pan balance. *Record* your data in a table **in your Journal**. Are these items best measured in kilograms, milligrams, or grams? Why did you choose the unit you did?

Safety First

Having the chance to do science is much more interesting than merely reading about it. Some of the scientific equipment that you will use is the same that scientists use in the field or in their laboratories. Of course, safety is of great importance in a laboratory. Most injuries are due to burns from heated objects or splatters and broken glass. The symbols shown below are used throughout your text to alert you to situations that require your special attention. A description of each symbol can be found on page 673 in the Safety Appendix. Following safety rules will protect you and others from injury and help you get more from your lab experiences.



SECTION REVIEW

1. What is a hypothesis?
2. How does a control differ from a variable?
3. What SI units are used to measure length, volume, and mass?
4. **Apply:** Identify the scientific methods that were used in the Find Out activity on page 5.
5. **Connect to Physics:** Find out the boiling point of water at sea level. What happens to this point at altitudes above sea level?

Skill Builder

Measuring in SI

Measure the volume of space in your classroom in cubic meters. Then figure out how much of this volume each student occupies. If you need help, refer to Measuring in SI in the **Skill Handbook** on pages 684-685.

SCIENCE & SOCIETY

1-4 The Impact of Science on Your Life

New Science Words

technology
ecology

Objectives

- State two ways in which life on Earth has been affected by technology in the life sciences.

Times Have Changed

Did you know that if you were born 100 years ago, you would probably not have lived past your first birthday? What a thought! When your parents were born, there were some places in the United States in which about one half of all infants died in their first year of life due to contaminated water and milk. This could still happen if your communities didn't have sanitation plants. Have you ever had a shot of penicillin to fight infection? Before the discovery of penicillin in 1940, infection was difficult to control, and many people died. Did you brush your teeth this morning? Before studies on why and how teeth decay, many people did not brush. Decayed teeth were pulled at an early age. Now most water systems are fluoridated, and tooth decay has decreased. Before modern techniques in food processing, such as irradiation of packaged foods, many diseases were acquired from contaminated foods. Sanitation, penicillin, fluoridated water, and irradiated food are examples of technologies that have extended lives. **Technology** is applied science, or the use of scientific knowledge to solve everyday problems or improve the quality of life.

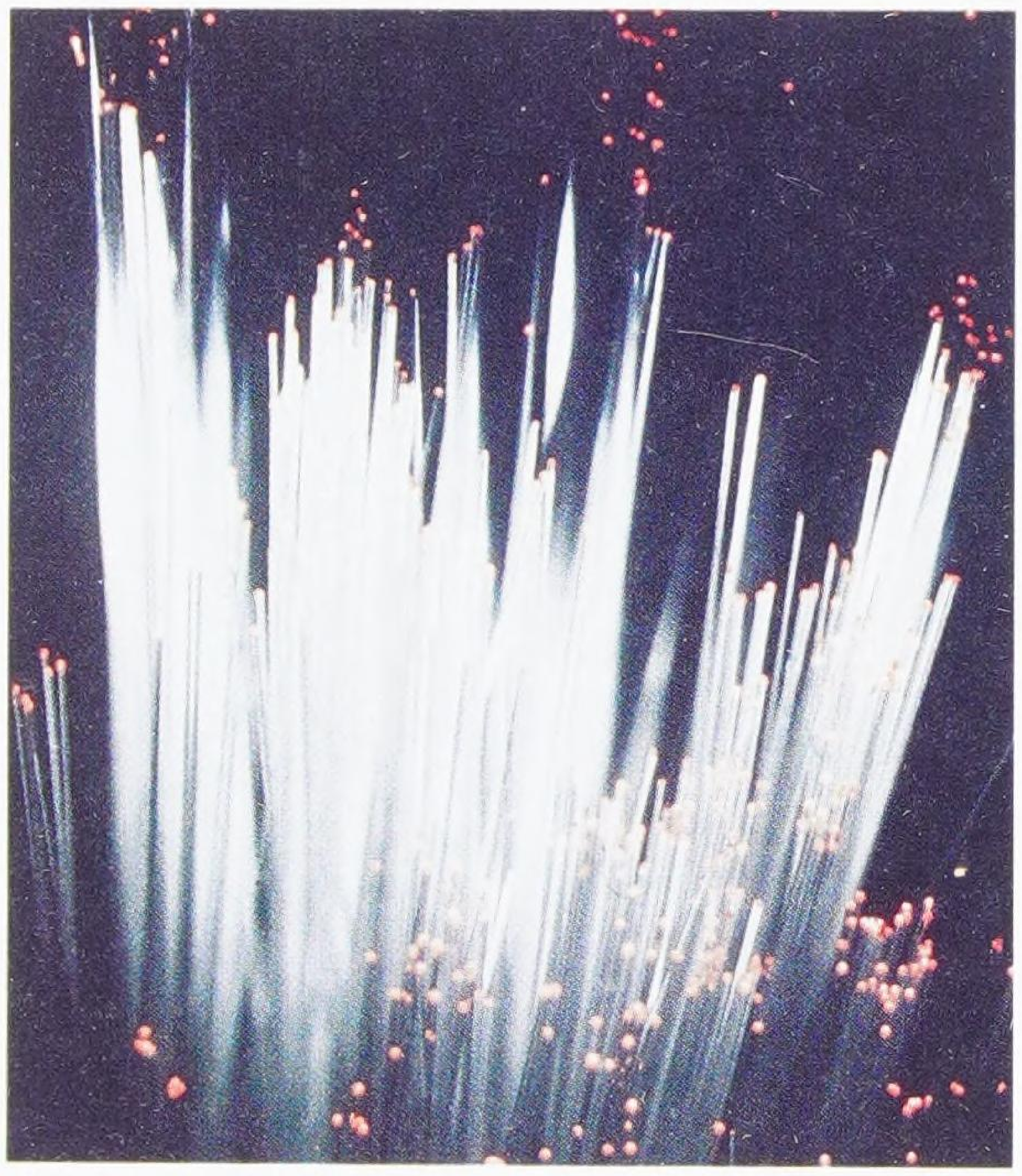


Figure 1-13. Optical fibers are used to transmit voices and data. They are also used in new forms of surgery.

Living with Technology

Years of research in the life sciences have enabled people to benefit directly from science economically, nutritionally, medically, and environmentally. Advances in agriculture allow you to have fish, meat, bread, and milk regularly. Because of agricultural research, farmers produce great quantities of healthful food at reasonable prices in many countries of the world.

Have all of the advances in the life sciences been beneficial? With the many great advances have also come many problems due to unforseen side effects. For example, you probably run a much greater chance of developing cancer than your ancestors of 100 years ago. The technology involved in the development of pesticides, food preservatives, and artificial sweeteners has contributed to increased incidence of cancer. Are the technologies the problem? Or is it how they are used that creates problems?

Now scientists are turning their energy to the environment. Many technologies seem to have a strong impact on the environment. **Ecology** is the study of how organisms interact with each other and the environment. Ecological problems such as global warming, the warming of Earth due to the buildup of carbon dioxide in the atmosphere, and deforestation, the destruction of forests that help take carbon dioxide out of the atmosphere, are sources of concern. Have these problems been caused by our own technology? Can we make use of all the knowledge we've gained through research to prevent these problems? Do we really know that technology is to blame for the problems of the environment? What is there in the framework of science that can help answer these questions?

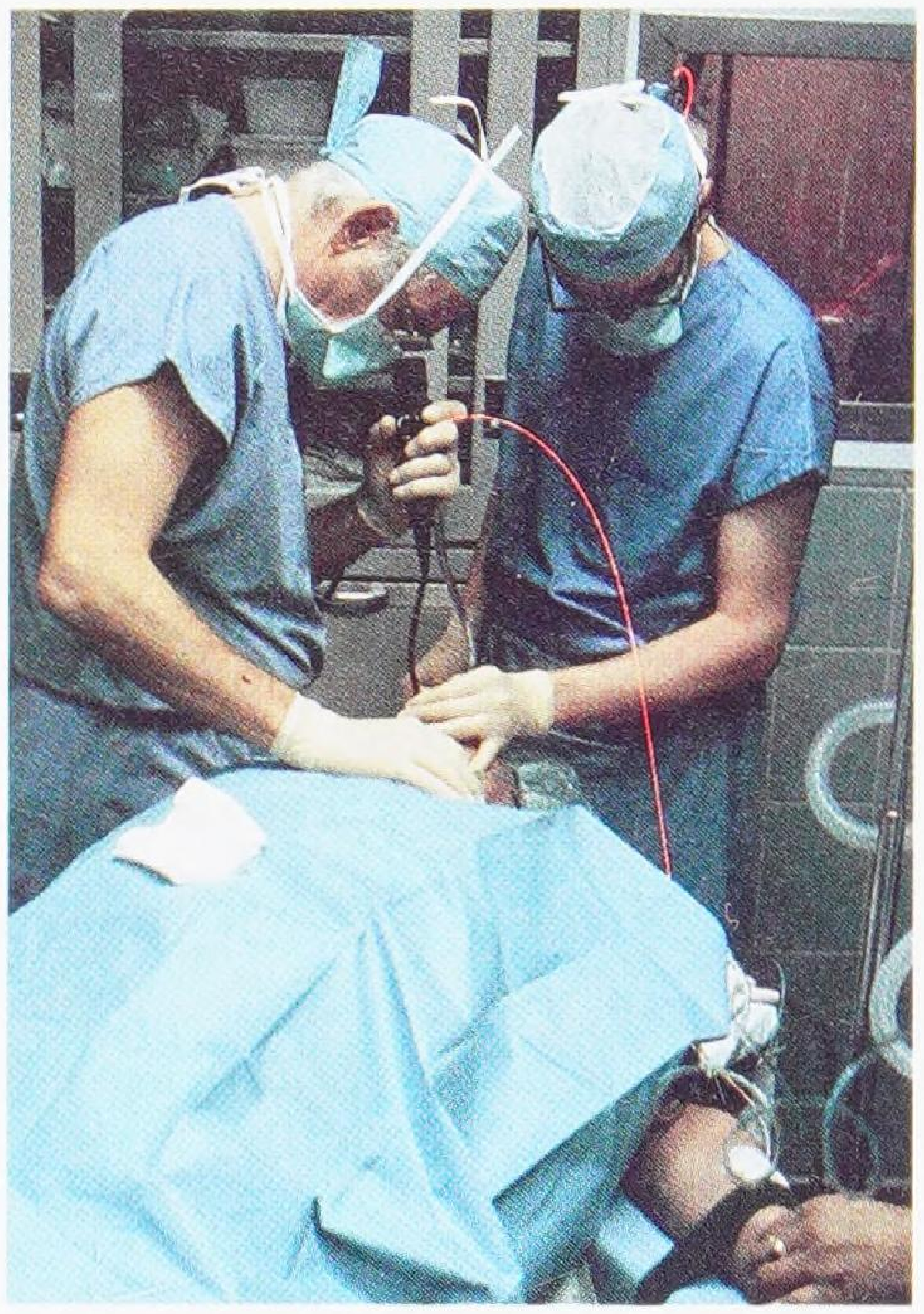


Figure 1-14. Laser surgery has reduced the time it takes to recover and has reduced infection.

SECTION REVIEW

1. Describe two ways in which Earth has benefitted from technology.
2. Describe two ways in which Earth may have been damaged as a result of technology.

SCIENCE & SOCIETY

You Decide!

How easy is it for a company to do what's best for the environment? Many fast-food companies are being urged to stop using styrofoam containers because the use of these products is thought to contribute to the destruction of the ozone layer. If companies go back to using paper products, however, where will these paper materials come from? If you were the company president, what would you have to do to make an informed decision?

ACTIVITY 1-1
Using a Scientific Method

Problem: *How does vinegar affect milk?*

Materials

- whole milk (300 mL)
- water (15 mL)
- vinegar (15 mL)
- 250-mL beakers (2)
- 50-mL graduated cylinder

Procedure

1. Use a reference book to find out what kind of substances milk and vinegar are.
2. Based on what you have read about milk and vinegar, make a **hypothesis** about how vinegar affects milk. Write your hypothesis in a data table like the one shown.
3. Use the following experiment to test your hypothesis:
   a. Label one beaker A and a second beaker B. Pour 150 mL of milk into each beaker.
   b. Add 15 mL of water to beaker A and 15 mL of vinegar to beaker B.
   c. Allow the beakers to remain undisturbed for three or four minutes.
4. *Record* what you *observe* about each beaker in the data table.
5. Using your observations, write a conclusion about each test in the data table.

Data and Observations

Effect of Vinegar on Milk

Test	Observation	Conclusion
A		
B		
Hypothesis		

Analyze

1. Which beaker was the control?
2. Which beaker was the variable?
3. Why did you use the same amount of milk in both beakers?
4. Why did you use the same amount of water and vinegar?

Conclude and Apply

5. How did vinegar affect the milk?
6. Why didn't water have an effect on the milk?
7. How does a variable differ from a control?

DISTILLED WHITE
VINEGAR
16 FL OZ (1 PT)
473mL

CHAPTER REVIEW

SUMMARY

1-1: Living Things

1. Organisms are made up of cells, use energy, move, respond, adjust, reproduce, grow and develop, and adapt to their environment.

2. Organisms need energy and materials.

3. Organisms interact with other organisms and nonliving things in their environment.

1-2: Where Does Life Come From?

1. Early experiments of Redi and Spallanzani tried to disprove the idea that living things come from nonliving matter.

2. Pasteur's experiment proved the theory that life comes from life, biogenesis.

3. Scientists try to explain how life began on Earth. Oparin's hypothesis, which says that energy combined early gases to form the chemical compounds of life, has been tested.

1-3: What is Science?

1. Scientists investigate observations that are made about living and nonliving things with the help of problem-solving techniques.

2. Scientists use SI measurements to gather measurable data.

3. Safe laboratory practices help you to learn more about science.

1-4: Science and Society: The Impact of Science on Your Life

1. Technology has improved health but also produced some harmful side effects.

KEY SCIENCE WORDS

a. **adaptation**
b. **biogenesis**
c. **cells**
d. **control**
e. **development**
f. **ecology**
g. **homeostasis**
h. **hypothesis**
i. **law**
j. **life span**
k. **organisms**
l. **response**
m. **scientific methods**
n. **spontaneous generation**
o. **stimulus**
p. **technology**
q. **theory**
r. **variable**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. the length of time an organism is expected to live
2. changes undergone during growth
3. a change in the environment that brings about a response
4. a living thing
5. the use of science for solving problems or improving life
6. theory that nonliving things produce living things
7. organized steps used to solve a problem
8. a prediction that can be tested
9. the units of life
10. a standard for comparing the result of an experiment

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. An infant cutting teeth is an example of _______.
   a. growth c. respiration
   b. development d. adaptation
2. A bright light that causes you to shut your eyes is a _______.
   a. need c. stimulus
   b. response d. variable
3. The source of energy for life is _______.
   a. the sun c. chlorophyll
   b. oxygen d. carbon dioxide
4. Living things are made up of about 70 percent _______.
   a. oxygen c. minerals
   b. carbon dioxide d. water
5. _______ disproved the theory of spontaneous generation.
   a. Oparin c. Pasteur
   b. Spallanzani d. Redi
6. Scientists think that _______ was missing from Earth's early atmosphere.
   a. ammonia c. methane
   b. hydrogen d. oxygen
7. _______ are inherited characteristics that help an organism to survive.
   a. Adaptations c. Raw materials
   b. Stimuli d. Theories
8. The _______ is the part of the experiment that is tested.
   a. conclusion c. control
   b. variable d. data
9. A(n) _______ is a prediction that has to be testable.
   a. experiment c. theory
   b. hypothesis d. law
10. The SI unit used to measure liquids is _______.
    a. meter c. gram
    b. liter d. degree

USING LAB SKILLS

11. Use a meter stick to measure the length and width of your lab table. Record your results. Explain why you used the unit numbers that you used.
12. Label two glasses, one A and the other B. Add 1/2 cup of water and 1/4 teaspoon of vinegar to each one. Then add 1/4 teaspoon of baking soda to A. Observe. Explain why one glass is the variable and why one is the control. Identify which is which.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Explain the difference between growth and development. Give an example.
14. How does technology help science?
15. What is the difference between a response and an adaptation?
16. Explain why living things need energy.

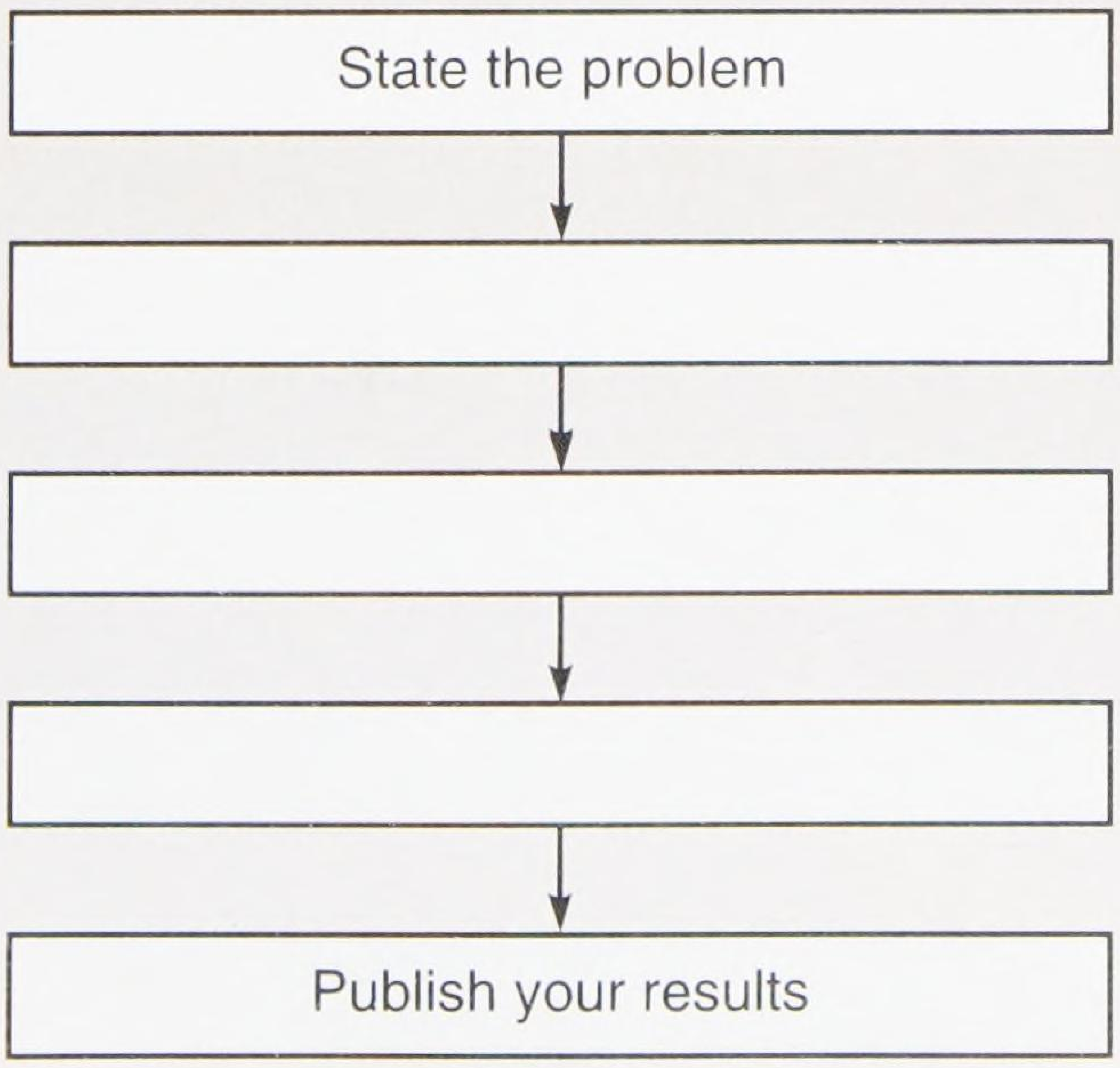
APPLY

17. How does SI benefit scientists in different parts of the world?
18. Using a bird as an example, explain how it has all the characteristics of living things.
19. If a plant had no carbon dioxide available, would this affect animal life?
20. Show how Pasteur correctly used scientific methods to disprove the theory of spontaneous generation.
21. How are stimulus and response related to homeostasis?

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Experimentation Skills:** Design an experiment to test the effects of the plant food on growing plants. Identify the scientific methods in your experiment.
2. **Concept Mapping:** Use the following terms to complete a chain-of-events concept map showing the order in which you might use scientific methods: *collect data, perform an experiment, state your hypothesis.*



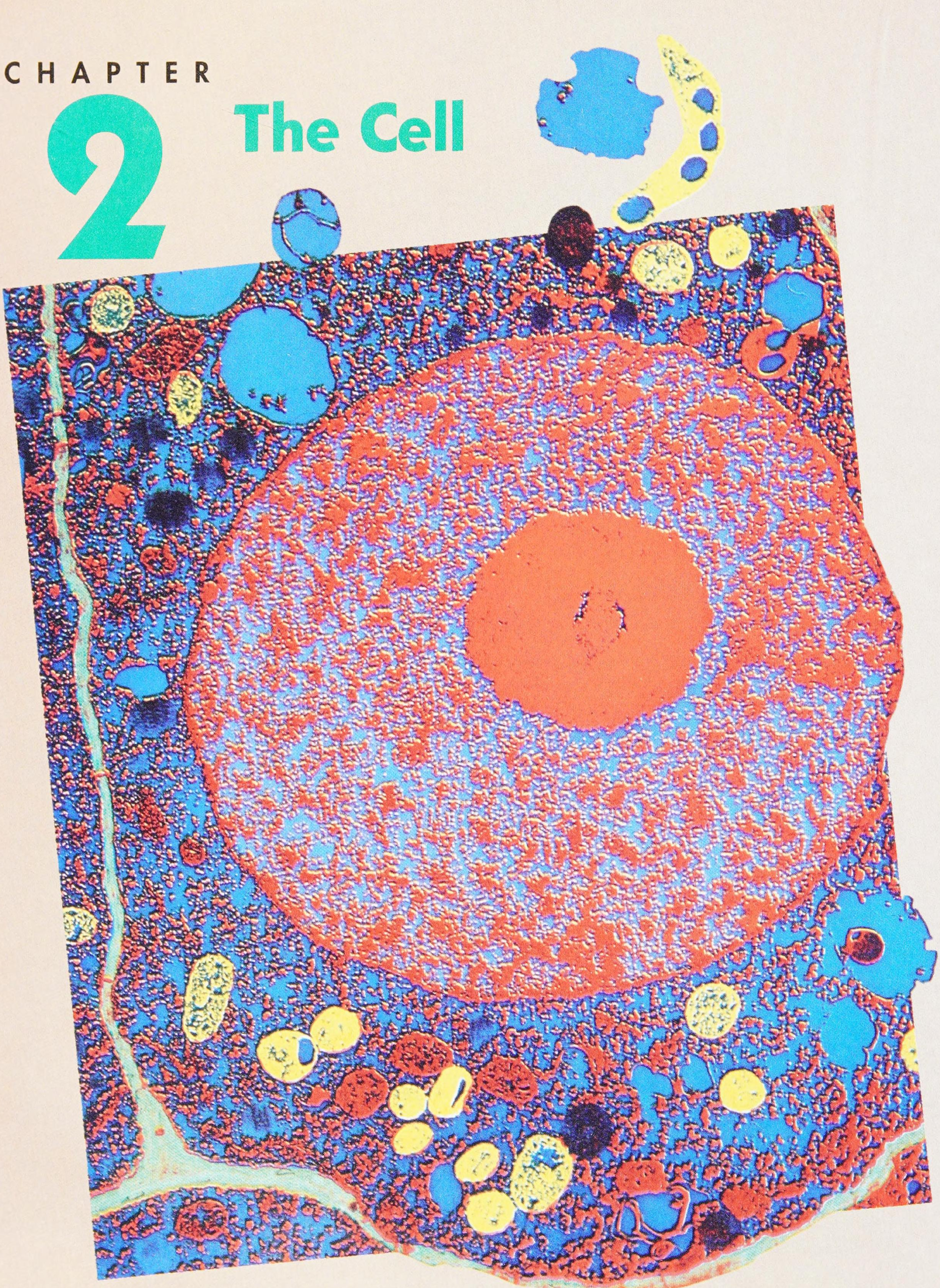
3. **Experimentation Skills:** You place one lima bean plant under a green light, another under a red light, and a third under a blue light. You measure their growth for 4 weeks to determine which color is most favorable to plant growth. What are the variables in this experiment? What is the hypothesis in this experiment? How could the experiment be improved?
4. **Observing and Inferring:** What evidence must scientists have to prove that cancer can be caused by cigarette smoking?
5. **Classifying:** Which type of measurement would you use for each of the following? Classify as meter, gram, cubic meter, degree, or liter.
   a. distance run
   b. how hot a pan of water is
   c. how much juice is in a glass
   d. your mass

PROJECTS

1. Interview people in your community whose jobs require a knowledge of life science. Make a Life Science Careers bulletin board. Summarize each person's job and what they had to study to prepare for that job.
2. Try to recreate Pasteur's experiment.

CHAPTER

2 The Cell

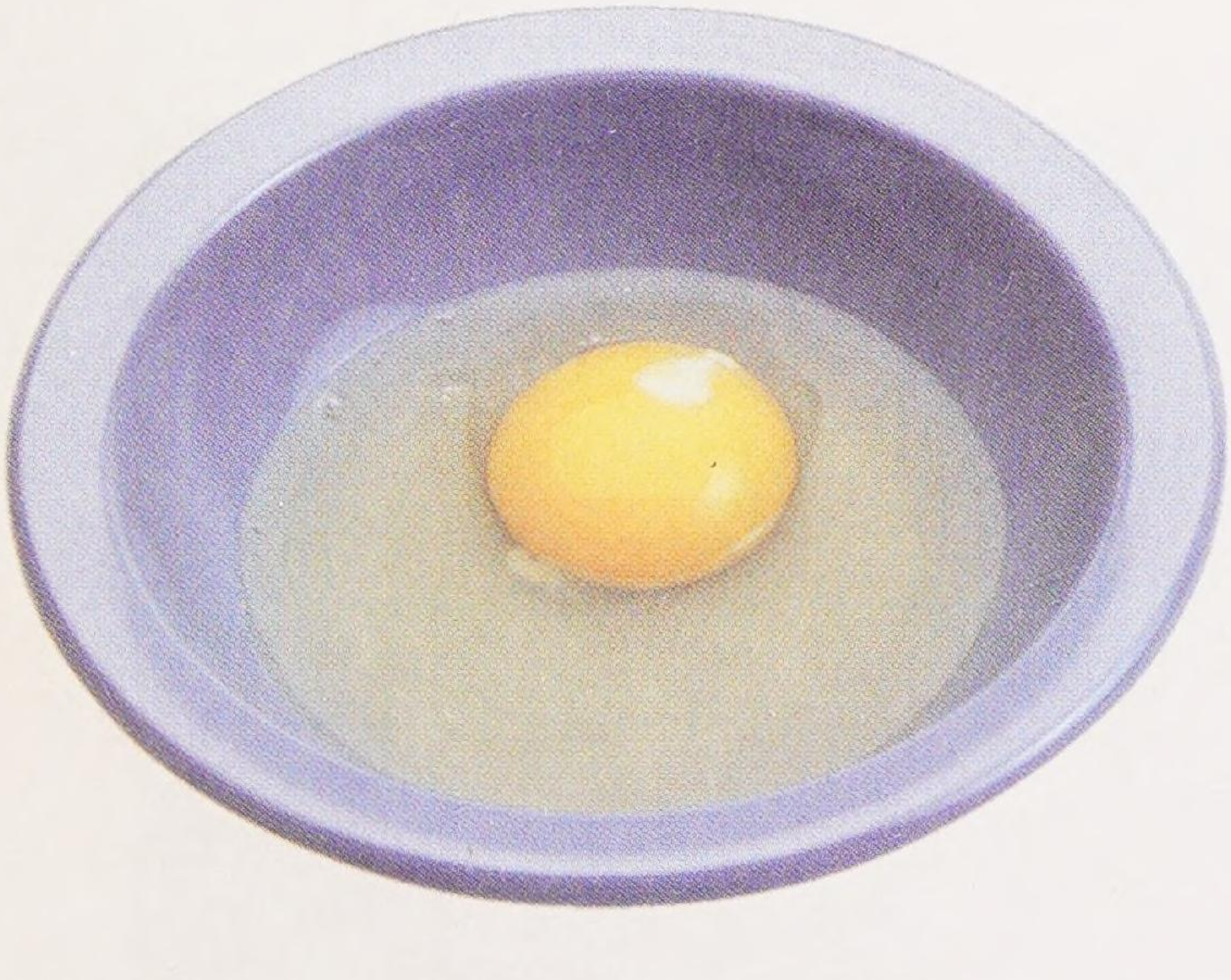


Most cells are too small to be seen without the help of a microscope. The plant cell on the opposite page has been magnified. But there are a few cells that can be seen using just your eyes. The largest known living cells are the yolks of bird eggs—not the white, just the yolk. How large is the cell of a chicken egg?

FIND OUT!

Find out that some cells can be seen without a microscope.

Break a chicken egg into a dish, and look at the yolk. How large do you think it is? *Estimate* its diameter. Then use a metric ruler to *measure* the diameter of your chicken yolk cell. With a hand lens, observe the yolk closely. Other cells that can be seen easily are large fish eggs. Discuss why some cells are large but most are very small.



Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 2-1 Cells: The Units of Life
- The Microscope: A Tool
- The Cell Theory

Section 2-2 Cell Structure
- An Overview of Cells
- Cell Membrane
- Cytoplasm
- Nucleus
- Organelles in the Cytoplasm
- Plant and Bacterial Cells

Section 2-3 Cell Organization
- How Cells Differ
- From Cell to System

Section 2-4 Science and Society
Organ Transplants
- Spare Parts for Broken Hearts

Previewing Science Skills

- In the **Skill Builders**, you will make a concept map, compare and contrast, and interpret scientific illustrations.
- In the **Activities**, you will observe, infer, compare, diagram, and draw conclusions.
- In the **MINI-Labs**, you will observe, identify, compare and infer.

What's next?

Now that you have looked at an extremely large cell, learn how the microscope helped in the discovery of cells of all sizes and in the development of the cell theory. You will also learn about microscopes that help reveal the detailed parts of cells. At the end of the chapter, you will see that many-celled organisms are organized with tissues, organs, and systems.

2-1 Cells: The Units of Life

New Science Words

compound light microscope
electron microscope
cell theory

Objectives

- Discuss the history leading to the cell theory.
- Explain the difference between the compound light microscope and electron microscope.
- State the cell theory.

The Microscope: A Tool

Cells are the smallest units that carry out the activities of life in organisms. Yet, as important as they are, you certainly don't see individual cells when you look at most plants or animals. You need a device, such as a magnifying glass or a microscope, to see most cells.

Trying to see separate cells in a large plant, like the one in Figure 2-1, is like trying to see individual bricks in a wall from three blocks away. If you start to walk toward the wall, it becomes easier to see individual bricks. When you get right up to the wall, you can see each brick in detail. A microscope performs a similar function. A microscope has one or more lenses that make an enlarged image of an object. Through these lenses, you are brought closer to the leaf, and you see the individual cells that carry on life processes.

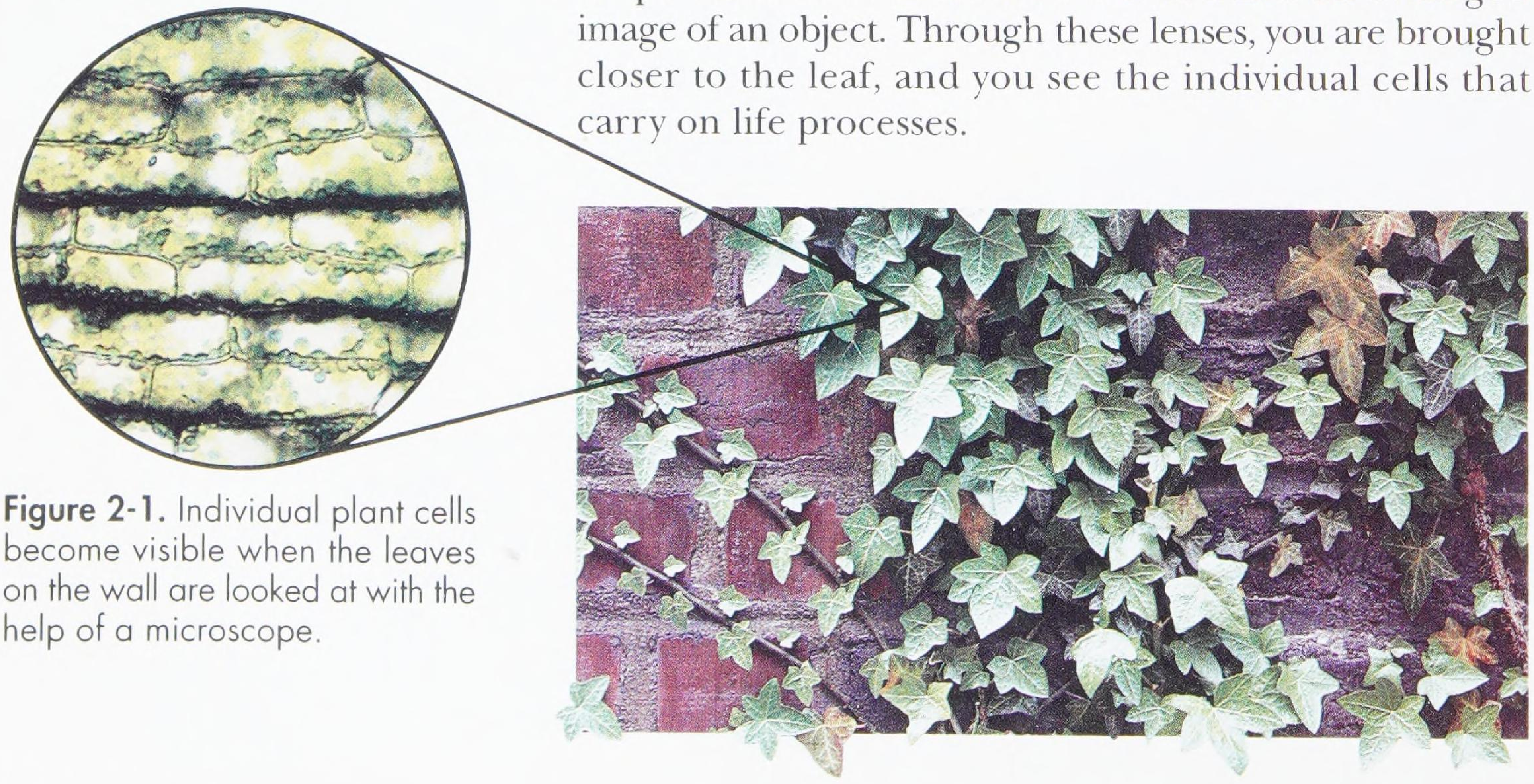


Figure 2-1. Individual plant cells become visible when the leaves on the wall are looked at with the help of a microscope.

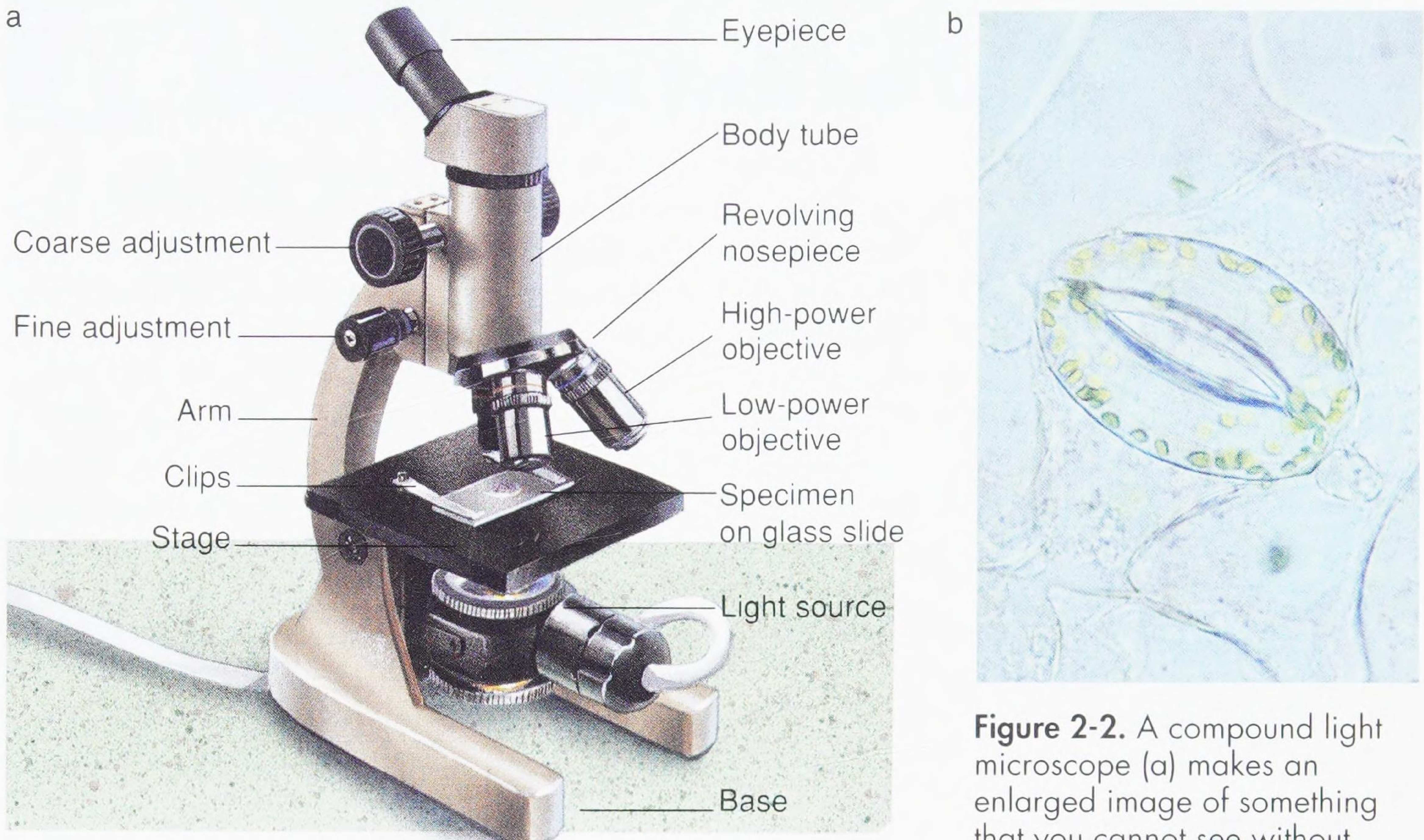


Figure 2-2. A compound light microscope (a) makes an enlarged image of something that you cannot see without help. Here (b) you see a small opening on the surface of a leaf.

Microscopes are simple or compound, depending on how many lenses they contain. A simple microscope is similar to a magnifying glass. It has only one lens. In 1590, a Dutch maker of reading glasses, Zacharias Janssen, put two magnifying glasses together in a tube. The result was the first crude compound microscope. By combining two lenses he got an image that was larger than an image made by only one lens. These early compound microscopes weren't satisfactory, however. The lenses would make a large image, but it wasn't always clear.

In the mid 1600s, Anton Van Leeuwenhoek, another Dutch scientist, made a simple microscope with a tiny glass bead for a lens. With it, he reported seeing things in pond water that no one had ever imagined before. His microscope could magnify up to 270 times. Another way to say this is that his microscope could make an image of an object 270 times larger than its actual size. Today we would say his lens had a power of 270X.

The microscope you will use in studying life science is a compound light microscope like the one in Figure 2-2. A **compound light microscope** lets light pass through an object and then through two or more lenses. The lenses enlarge the image and bend the light toward your eye. It has an eyepiece lens and an objective lens. An eyepiece

MINI-Lab

How are objects magnified?

Early scientists used various tools to help view objects. Try looking at a newspaper through the curved side of an empty glass, the flat bottom of an empty glass, a bowl filled with water, and a magnifying glass. *Compare* how well you can see through each. What did early scientists learn by using such tools?

lens usually has a power of 10X. An objective lens may have a power of 43X. Together, they have a total magnification of 430X (10X times 43X). Some compound microscopes have more powerful lenses that magnify an object up to 2000 times (2000X) its original size.

Your classroom may have a stereoscopic (stereo) light microscope that gives you a three-dimensional view of an object. Stereo microscopes are used to look at thick structures that light can't pass through, such as whole insects or leaves, or your fingerprints.

Things that are too small to be seen with a light microscope can be seen with an electron microscope. Instead of using lenses to bend beams of light, an **electron microscope** uses a magnetic field to bend beams of electrons. Electron microscopes can magnify images more than 300 000 times. Figure 2-3 shows the kind of detail that can be seen with an electron microscope.

There are several kinds of electron microscopes. One is the transmission electron microscope (TEM), which is used to study parts inside a cell. The object has to be sliced very thin and placed in a vacuum. There is no air in a vacuum. As a result, only dead cells can be observed this way. A scanning electron microscope (SEM) is used to see the surfaces of whole objects. With an SEM, you can view and photograph living cells. From the time of Van Leeuwenhoek until the present, the microscope has been a valuable tool for studying cells. You will see how it was used to develop the cell theory.

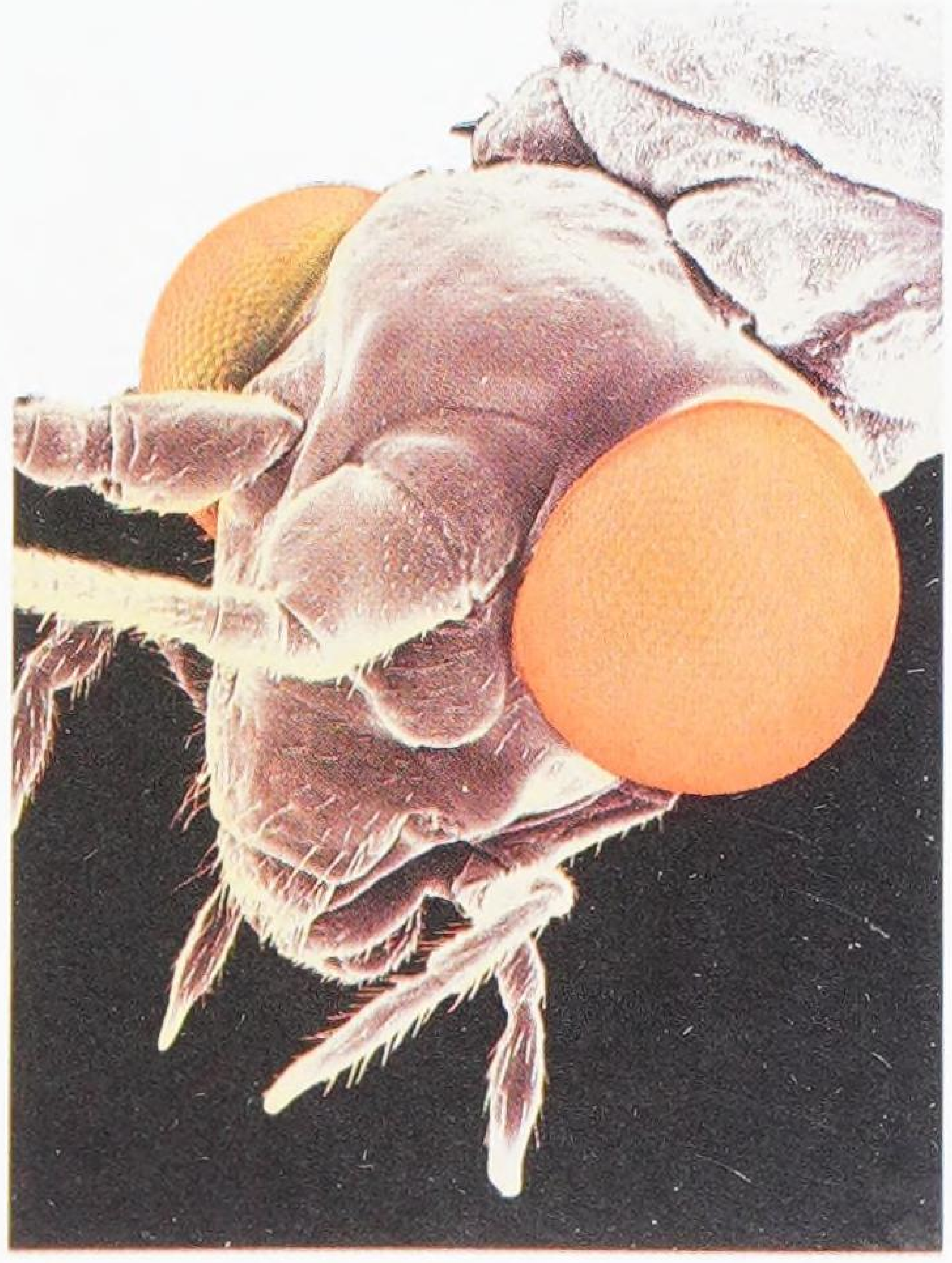
Science and MATH

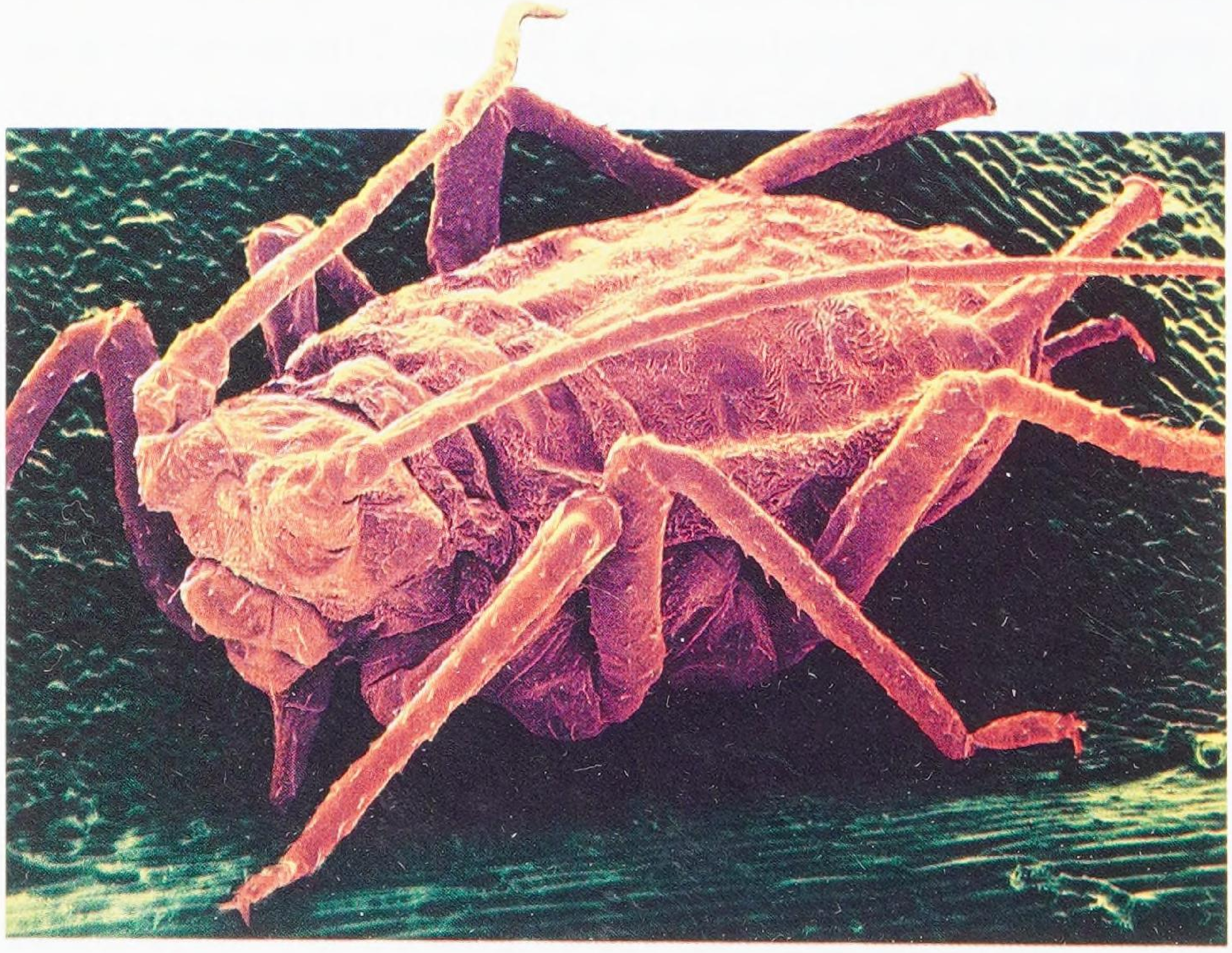
Calculate the total magnification of your microscope if the eyepiece is 10X and the high power objective is 40X.

Connect to... Physics

A magnifying glass is a convex lens. All microscopes use one or more convex lenses. Find out the shape of a convex lens and describe it. Explain how it magnifies.

Figure 2-3. The electron microscope shows details on these insects that can't be seen with a compound microscope.





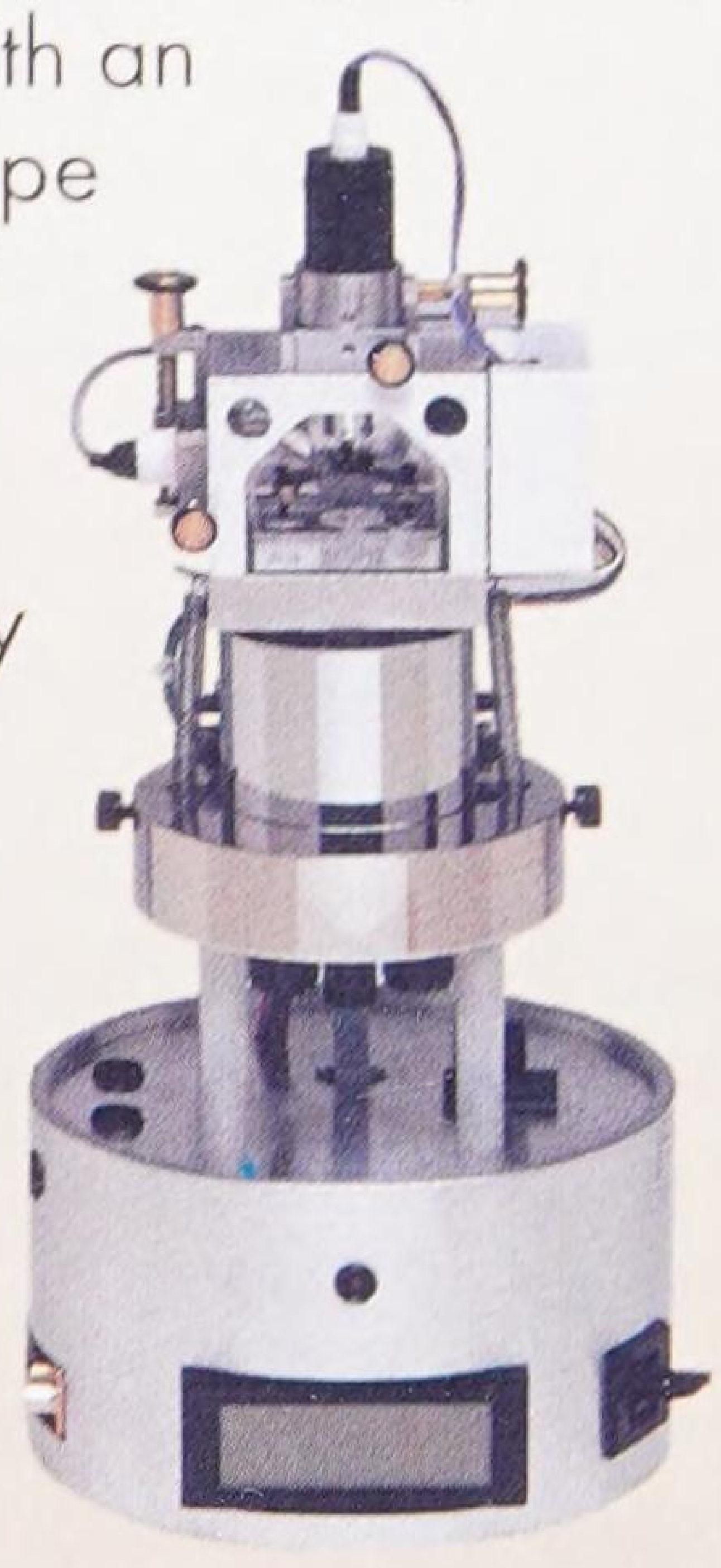
TECHNOLOGY

A Touch of Diamonds

One of the newest members of the microscope family is the atomic-force microscope. It makes use of a diamond-tipped probe that moves across the surface of a specimen. The tip moves up and down as it probes the hills and valleys of tissues. Just as a phonograph needle traces the grooves in a record, the diamond tip is moved up and down by the force of electrons on the surface of the atoms making up the tissue. As it does, it traces the shape of the surface of a cell. This tracing is then projected as a visual image on a screen. The diamond used is so small that human eyebrow hairs are used to move it when the probe is being assembled.

The atomic-force microscope "sees" individual living cells without damaging them. The first video made with an atomic-force microscope shows the clotting of blood. With this microscope, such events can now be watched as they take place.

Think Critically: How might an atomic-force microscope help medical research?



The Cell Theory

During the centuries when explorers like Columbus and Magellan set out to find new lands, scientists were busy observing everything they could about the smaller world around them. Curiosity made them look through their microscopes and lenses at mud from ponds and drops of rainwater. They examined blood and scrapings from their own teeth.

What did Robert Hooke see when he looked at cork?

Cells weren't discovered until the microscope was improved. In 1665, Robert Hooke, an English scientist, made a very thin slice of cork and looked at it under his microscope. To Hooke, the cork seemed to be made up of little empty boxes, which he called *cells*. The drawing of cork cells reproduced in Figure 2-4, was made by Robert Hooke more than 300 years ago. Actually, Hooke was not aware of the importance of what he was seeing.

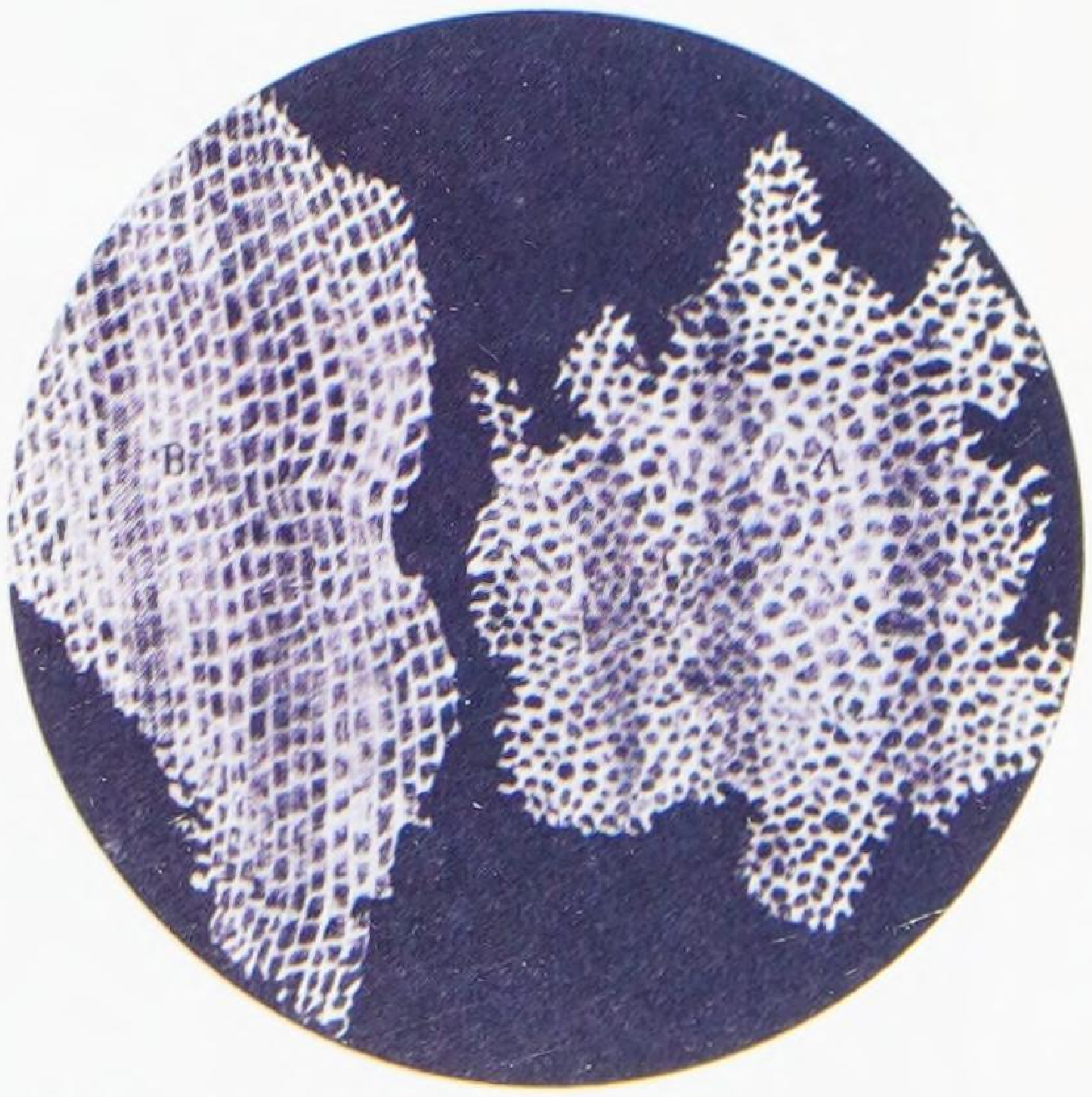


Figure 2-4.
Hooke's Cork Cells

In 1838, Matthias Schleiden, a German scientist, used a microscope to study plant parts. He concluded that all plants were made of cells. Just a year later, another

In Your JOURNAL

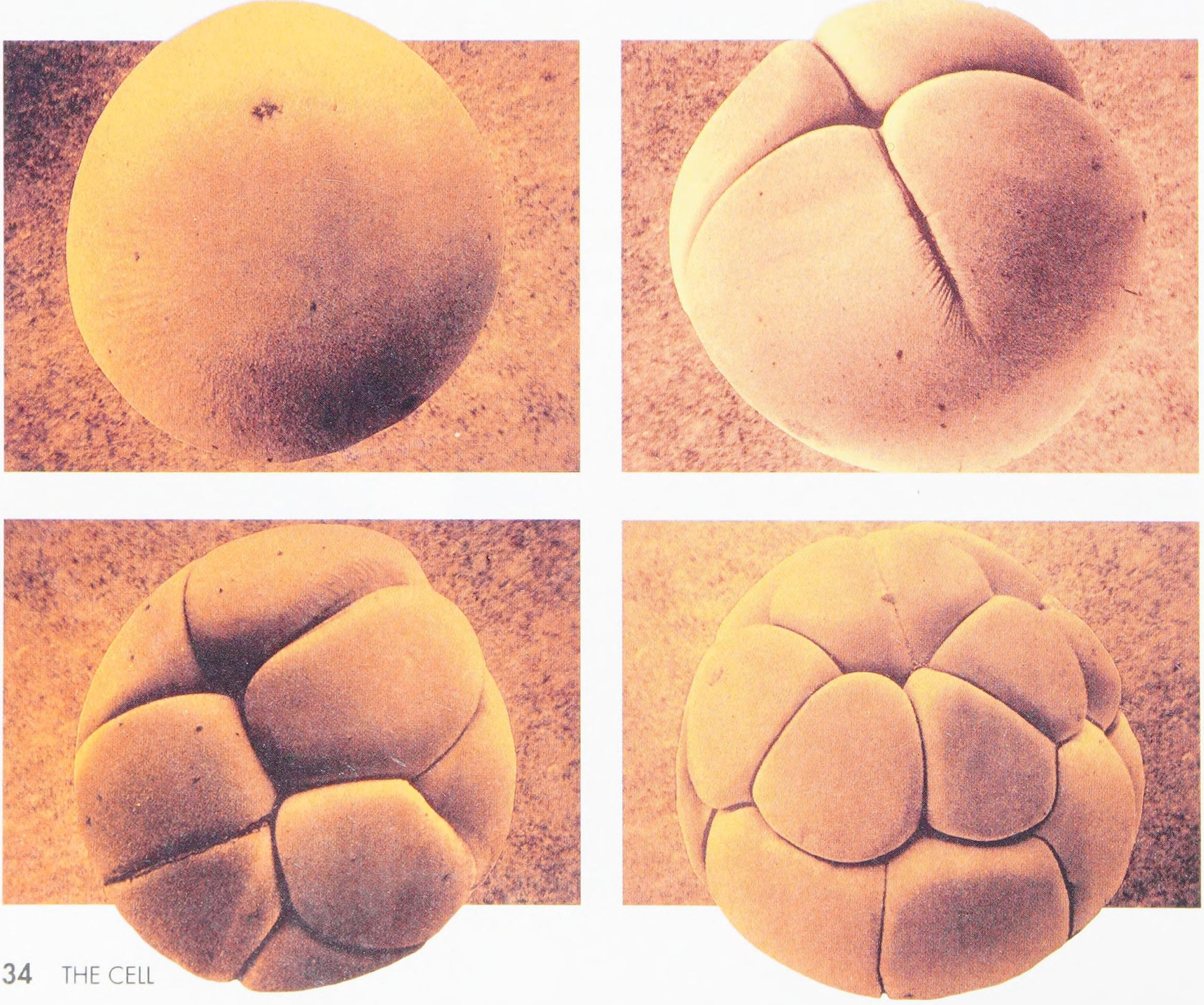
Put yourself in the shoes of a Schleiden, Schwann, or Van Leeuwenhoek. Consider the times in which they lived. **In your Journal**, write a dialogue between the scientist and his son or daughter, as he tries to explain his discovery.

German scientist, Theodor Schwann, after observing many different animal cells, concluded that all animals were made up of cells. Together, they became convinced that all living things were made of cells.

About 15 years later, a German doctor, Rudolph Virchow, hypothesized that new cells don't form on their own. Instead, cells divide to form new cells. This was a startling idea. Remember that at that time, people thought earthworms fell from the sky when it rained. They thought that life came about spontaneously. What Virchow said was that every cell that is or has ever been came from a cell that already existed. The observations and conclusions of Schleiden, Schwann, Virchow, and other scientists became known as the cell theory. The major ideas of the **cell theory** are:

1. All organisms are made up of one or more cells.
2. Cells are the basic units of structure and function in all organisms.
3. All cells come from cells that already exist.

Figure 2-5. Cells divide to produce new cells. Pictured below are four early stages in the development of a frog.



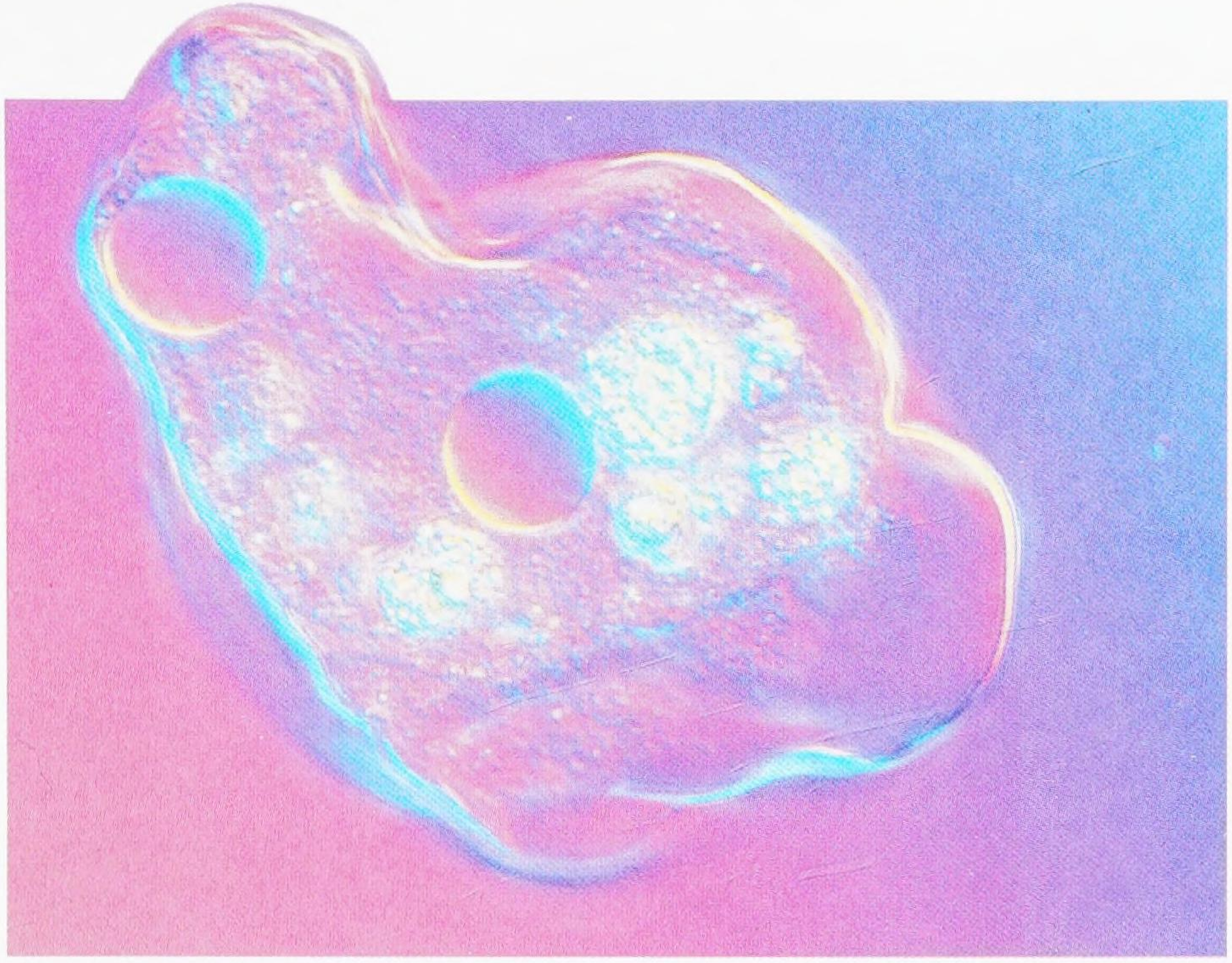


Figure 2-6. One-celled organisms like this amoeba may look simple, but they carry on many complex life processes.

Did You Know?

The most rapidly growing animal is the blue whale. It develops from an ovum (egg) with a mass of less than a milligram into a 26-ton adult in less than 2 years. All of this growth is the result of the division and metabolism of cells.

What are the three parts of the cell theory?

The cell theory is one of the major theories in science. It is not based on the hypotheses and observations of only one person, but is result of the discoveries of many scientists. Today it serves as the basis for scientists who study the parts of cells, how cells are organized, and how cells and organisms reproduce and change through time.

SECTION REVIEW

1. Explain why the invention of the microscope was important in the study of cells.
2. How is a compound light microscope different from an electron microscope?
3. Why is the cell theory important?
4. **Apply:** Why would it be better to be able to see the details of living cells than dead cells?
5. **Connect to Earth Science:** Find out about telescopes. How do they compare with microscopes?

Skill Builder

Concept Mapping

Using a network tree concept map, show the differences between compound light microscopes and electron microscopes. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

2-2 Cell Structure

New Science Words

cell membrane
cytoplasm
organelles
nucleus
chromatin
endoplasmic reticulum
ribosomes
Golgi bodies
mitochondria
lysosomes
vacuoles
cell wall
chloroplasts

Objectives

- Diagram a plant cell and an animal cell; identify the parts and the function of each part.
- Describe the importance of the nucleus in the cell.
- Compare and contrast prokaryotic and eukaryotic cells.

An Overview of Cells

In contrast to the dry cork boxes that Hooke saw, living cells are dynamic and have several things in common. They all have a membrane and a gel-like material called cytoplasm inside the membrane. In addition, they all have something that controls the life of the cell. This control center is either a nucleus or nuclear material.

Scientists have found that there are two basic types of cells. Cells that have no membrane around their nuclear material are prokaryotic cells. Bacteria and cells that form pond scum are prokaryotic cells. A eukaryotic cell has a nucleus with a membrane around it. The animal and plant cells in this chapter are all eukaryotic cells.

How does a prokaryotic cell differ from a eukaryotic cell?

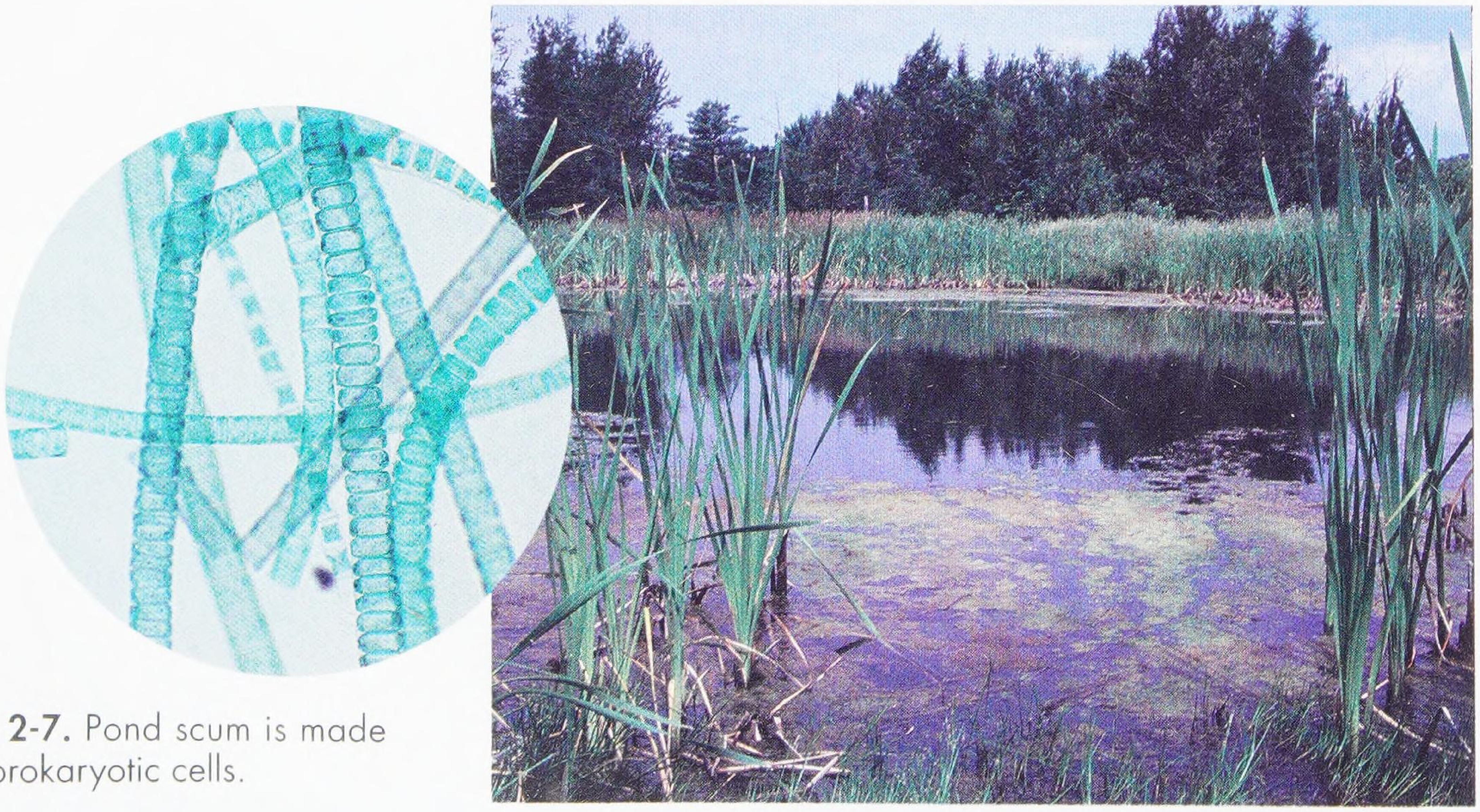


Figure 2-7. Pond scum is made up of prokaryotic cells.

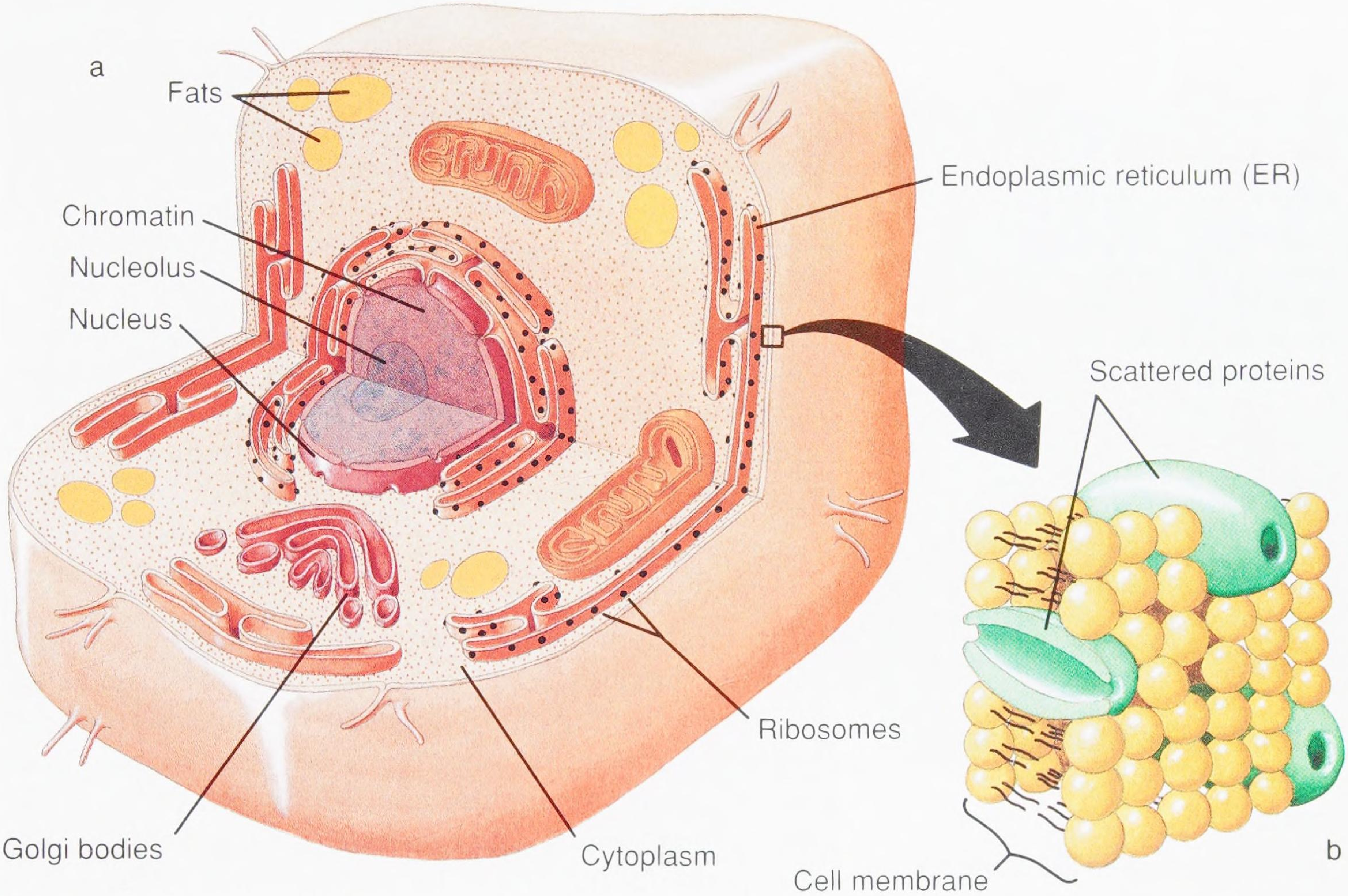


Figure 2-8. The parts of a typical animal cell are shown above (a). The cell membrane is made up of two layers (b).

Cell Membrane

Each cell in your body is constantly active and has a specific job to do. The activities in your cells might be compared to a business that operates 24 hours a day making dozens of different products. It operates inside a building. Only materials that are needed to make specific products are brought into the building. Finished products are then moved out. A cell is similar. It functions within a structure called the cell membrane.

The **cell membrane** is a structure that forms the outer boundary of the cell and allows only certain materials to move into and out of the cell. The membrane as shown in Figure 2–8, is flexible. It is made up of a double layer of fats with some proteins scattered throughout. The cell membrane helps to maintain a chemical balance between materials inside and outside the cell. Food and oxygen move into the cell through the membrane. Waste products also leave through the membrane. In Chapter 3, you will learn that different types of substances enter and leave the cell in different ways.

Connect to...
Earth Science

The cell membrane has been described as two layers of fats with large proteins here and there among the fat molecules. In some ways, it is similar to an ocean with icebergs. Icebergs are large pieces of ice that move randomly through the ocean. Explain how the iceberg analogy helps you visualize how the large protein molecules behave in a cell membrane.

MINI-Lab

What is cytoplasm like?

Cytoplasm of cells is a mixture of proteins, fats, carbohydrates, salts, water, and many other chemicals. The solid particles are suspended in the liquid part of this mixture. The cytoplasm can be gel-like. Make a *model* of cytoplasm. Fill a beaker with 100 mL of water. Add unflavored gelatin and stir. Shine a flashlight through the beaker. **In your Journal,** describe what you see. How does a model cell help you understand what a real one is like?

Cytoplasm

Cytoplasm is the gel-like material inside the cell membrane. Cytoplasm contains a large amount of water and many chemicals and structures that carry out the life processes in the cell. Unlike a gelatin dessert however, cytoplasm constantly moves or streams.

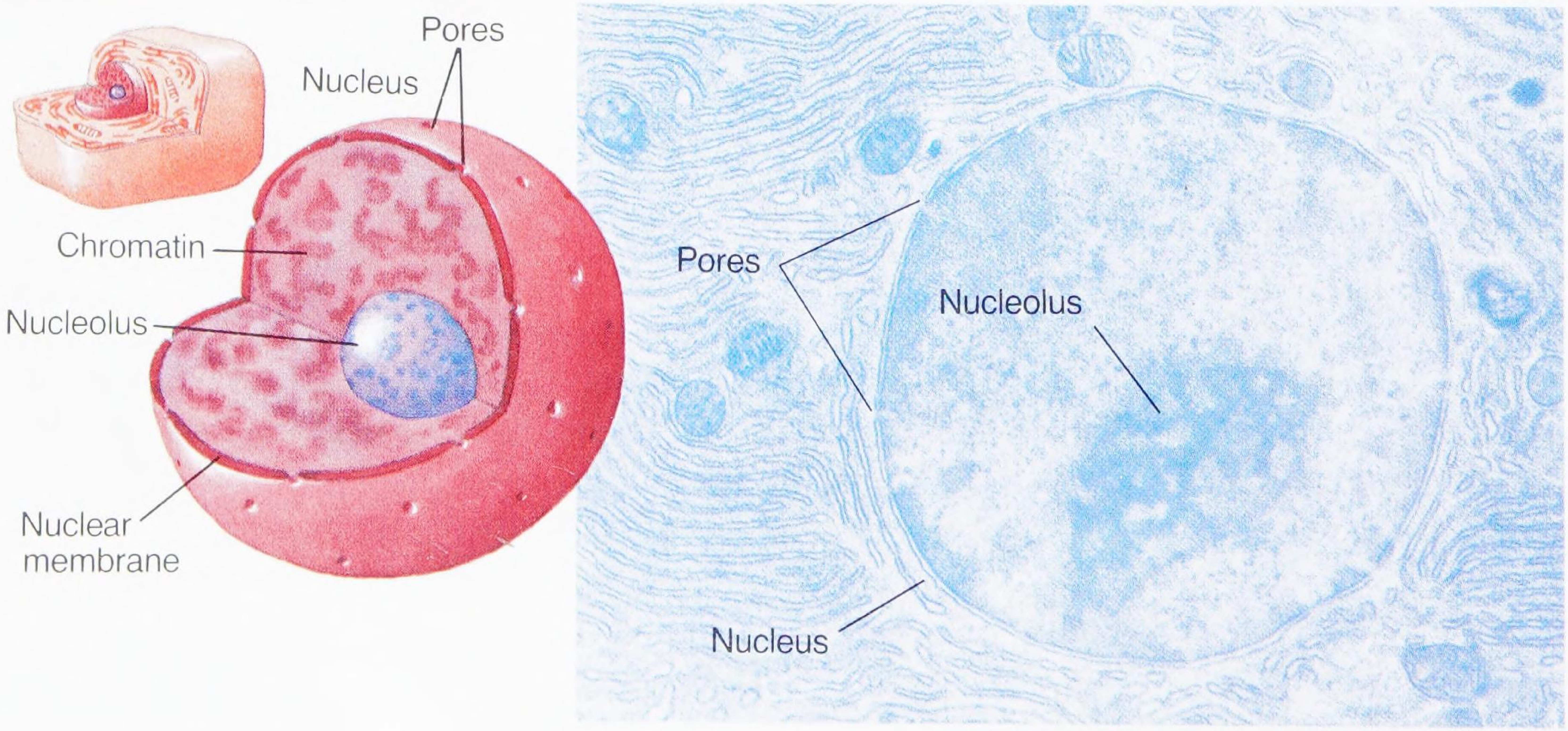
The structures within the cytoplasm of eukaryotic cells are **organelles.** Each one has a specific job. Some organelles break down food. Others move wastes to be expelled from the cell. Still others store materials. Most organelles are surrounded by membranes.

Nucleus

The largest organelle in the cytoplasm of a eukaryotic cell is the **nucleus,** a structure that directs all the activities of the cell. The nucleus is like a manager who directs everyday business for a company. The nucleus contains genetic blueprints for the operations of the cell in the form of long strands called **chromatin.** Chromatin is made up of proteins and DNA, the chemical that controls the activities of the cell. When a cell begins to divide, the strands of chromatin become thick and take on the form of chromosomes, which are easier to see. A structure called a nucleolus is also found in the nucleus.

A nucleus is separated from the cytoplasm by a nuclear envelope. Materials enter and leave through openings in the envelope.

Figure 2-9. A nucleus is surrounded by a membrane, or envelope. DNA in the nucleus controls the activities in the cell.



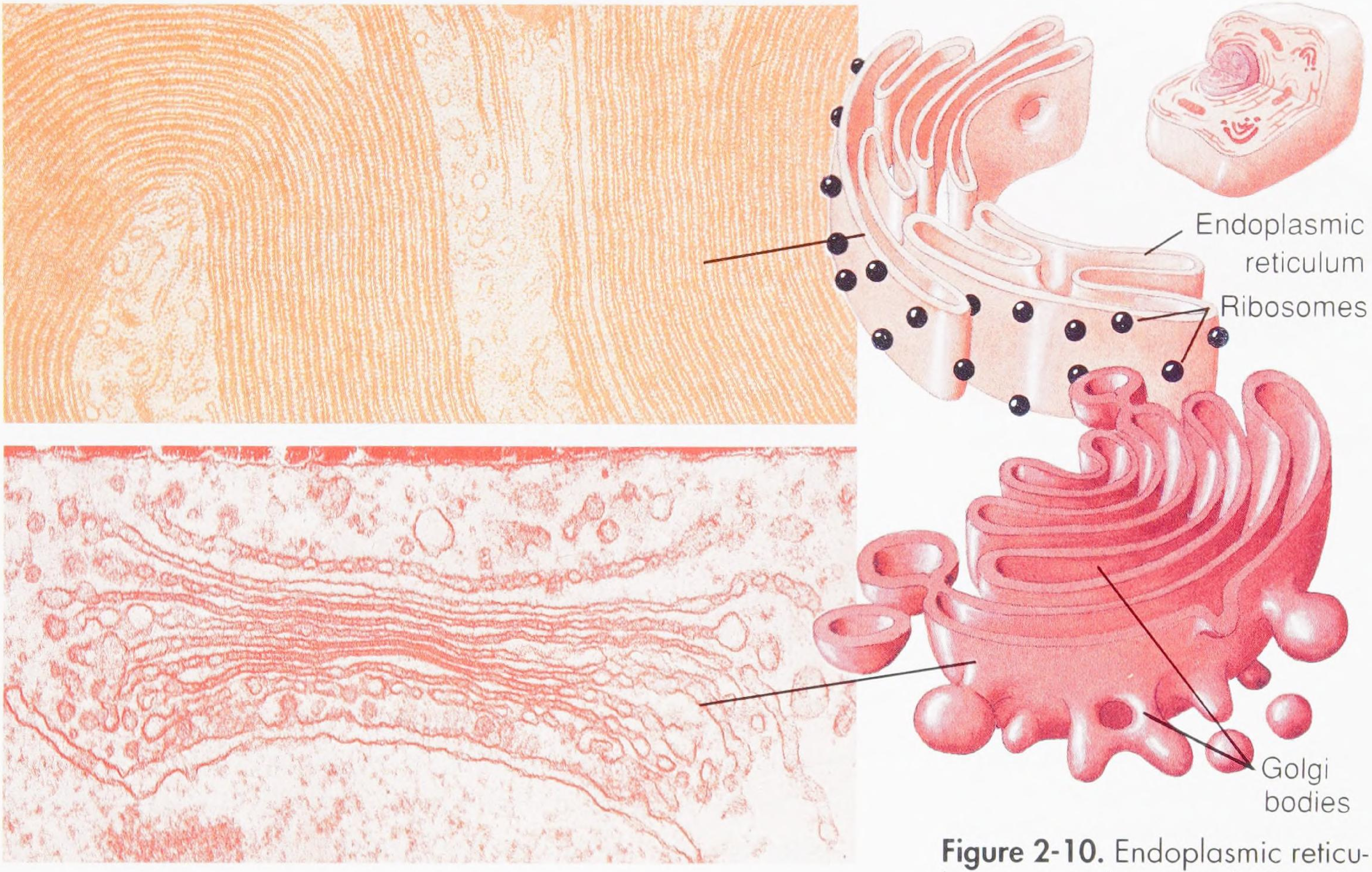


Figure 2-10. Endoplasmic reticulum is smooth or rough. Proteins are made on ribosomes. Golgi bodies may move materials to the outside of the cell.

Organelles in the Cytoplasm

The **endoplasmic reticulum** (**ER**) is a folded membrane that moves materials around in the cell. The ER extends from the nucleus to the cell membrane and takes up quite a lot of space in some cells. The ER is like a system of conveyor belts in a business that moves material from one place to another.

One chemical that takes part in nearly every cell activity is protein. Proteins are found in cell membranes. Other proteins are needed for chemical reactions that take place in the cytoplasm. Cells make their own proteins on small structures in the cytoplasm called **ribosomes.** Ribosomes receive directions from the nucleus on how to make specific proteins. Some ribosomes are scattered in the cytoplasm. Others are attached to the ER. Ribosome parts are made in the nucleolus.

Where are ribosomes found?

In a business, products are made, packaged, and moved to loading docks to be carried away. Structures called Golgi bodies are stacks of membrane-covered sacs that move proteins to the outside of the cell. **Golgi bodies** are the packaging and secreting organelles of the cell. When something is secreted, it is given off by the cell.

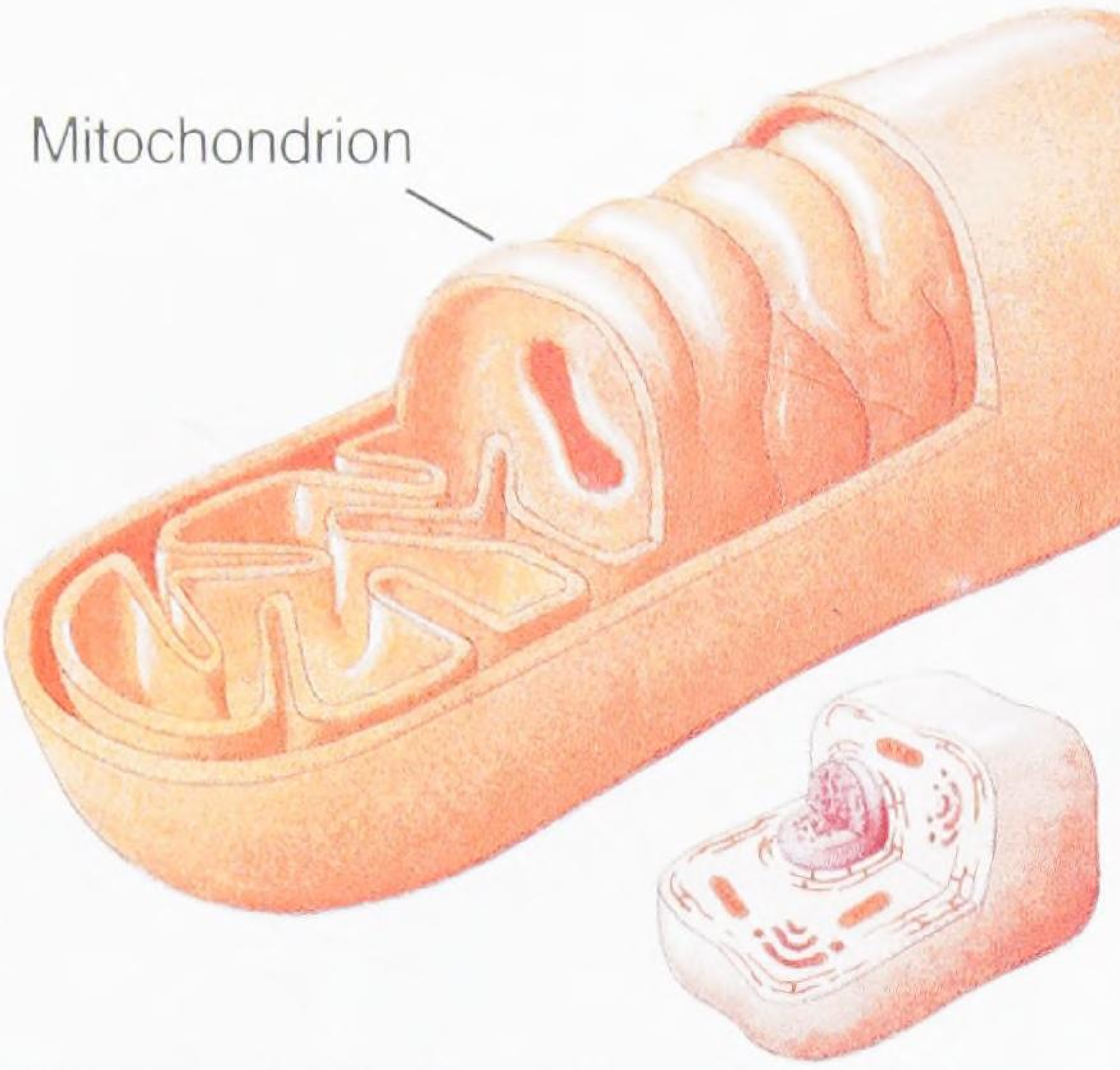


Figure 2-11. Energy is released in mitochondria.

Cells require a continuous supply of energy. **Mitochondria** are organelles where food molecules are broken down and energy is released. Just as a power plant supplies energy to a business, mitochondria generate energy for the cell. Some types of cells are more active than others. Muscle cells, which are always undergoing some type of movement, have large numbers of mitochondria. Why would active cells have more mitochondria?

An active cell also constantly produces waste products. In the cytoplasm, organelles called **lysosomes** contain chemicals that digest wastes and worn-out cell parts. When a cell dies, chemicals in the lysosomes act to quickly break down the cell. In a healthy cell, the membrane around the lysosome keeps it from breaking down the cell itself.

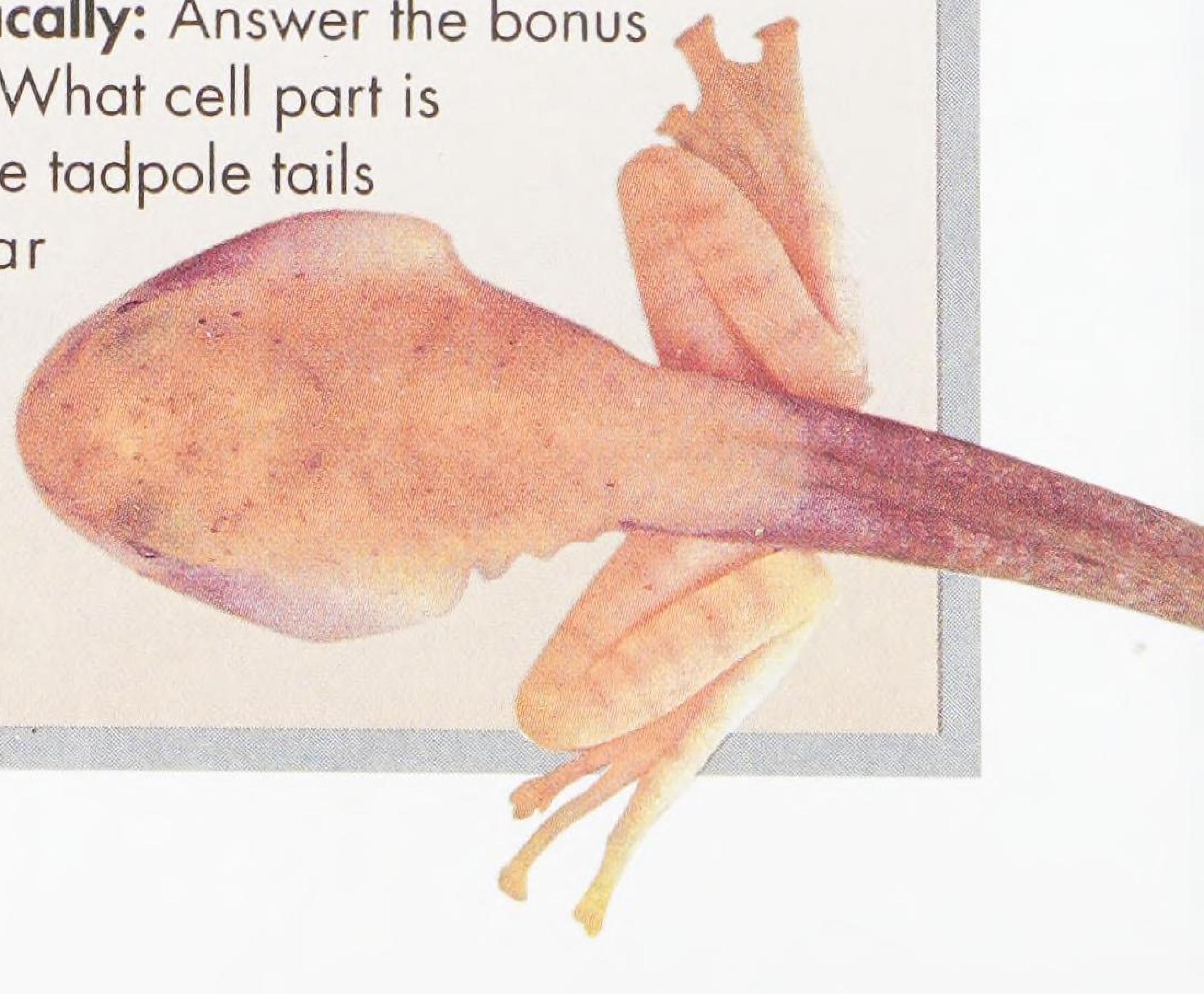
PROBLEM SOLVING

A Tale of a Tail

In September, Mrs. Tallman's class studied the parts of plant and animal cells.

In the spring, while on a field trip, the class captured tiny tadpoles in a local stream. Mrs. Tallman showed the students how to care for the tadpoles in the classroom. Gradually, as the animals grew, it was obvious that their bodies were changing shape. Back and front legs grew out, and the mouth expanded from a small hole to a large opening capable of swallowing large insects. In addition, the tails started to disappear. Mrs. Tallman told the whole class that there would be a bonus question about the tadpoles on the test on animals. For a study hint, she told them to look back at their notes on cells. What do changes in the body parts of the tadpoles have to do with cells?

Think Critically: Answer the bonus question: What cell part is making the tadpole tails disappear and why?



Many businesses have warehouses for storing products until they are sold. **Vacuoles** are storage areas in cells. They may store water, food, or waste products. Figure 2-12 shows that a vacuole may take up most of the space in a plant cell. In animal cells, vacuoles are small.

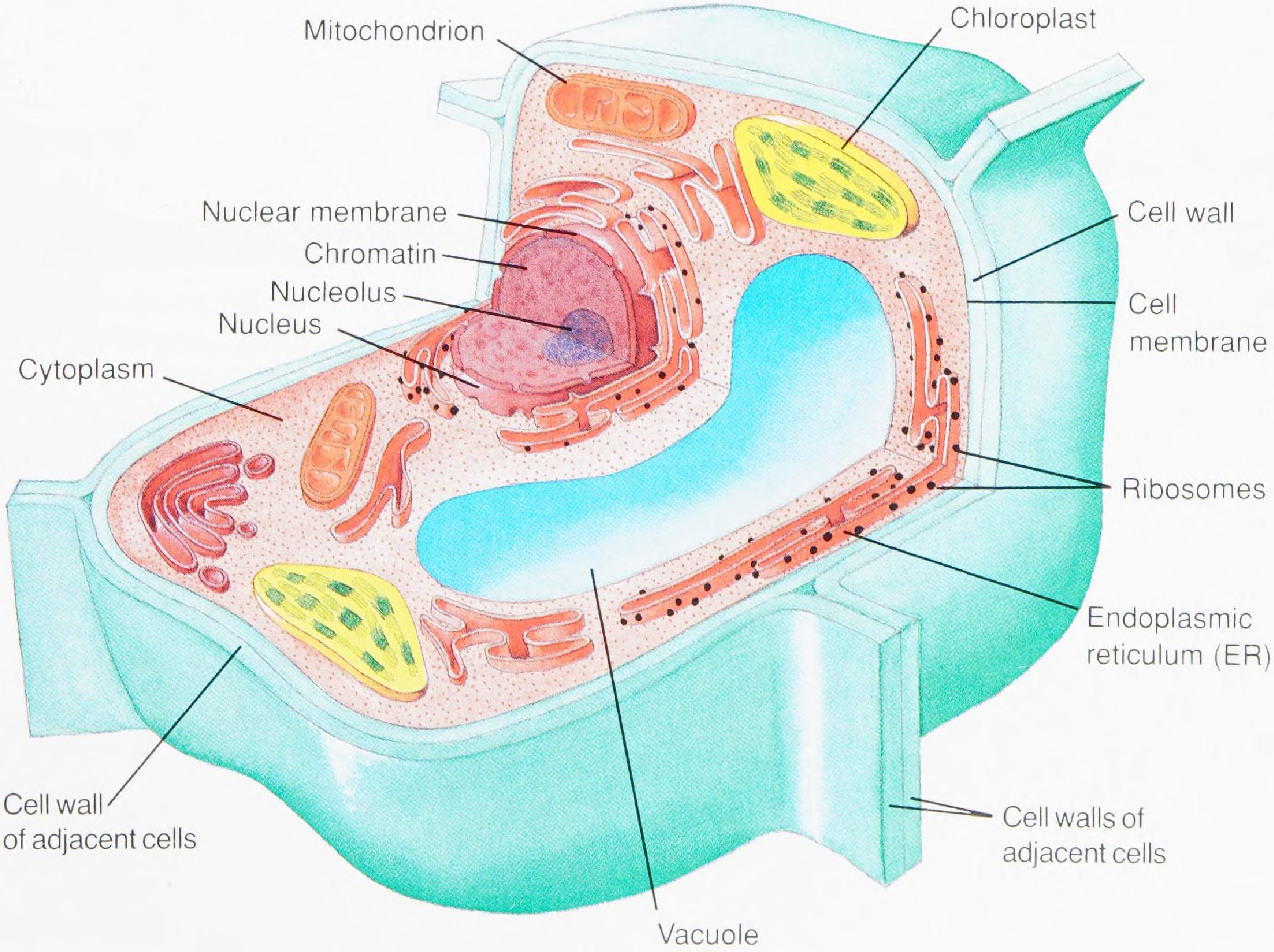
Plant and Bacterial Cells

How do plant and animal cells differ?

The major difference between an animal cell and a plant cell is that plant cells have cell walls. The **cell wall** is a rigid structure outside the cell membrane that supports and protects the plant cell. It is made of bundles of tough cellulose fibers and other materials made by the cell.

Plant cells also differ from animal cells because they can make their own food. **Chloroplasts** are organelles in plant cells in which light energy is changed into chemical energy in the form of a sugar called glucose. The chemical in chloroplasts that traps light energy is chlorophyll, the pigment that reflects green light.

Figure 2-12. The parts of a plant cell are shown below. Notice the thick cell wall and the chloroplasts.


Mitochondrion
Chloroplast
Nuclear membrane
Chromatin
Nucleolus
Nucleus
Cytoplasm
Cell wall
Cell membrane
Ribosomes
Endoplasmic reticulum (ER)
Cell wall of adjacent cells
Cell walls of adjacent cells
Vacuole

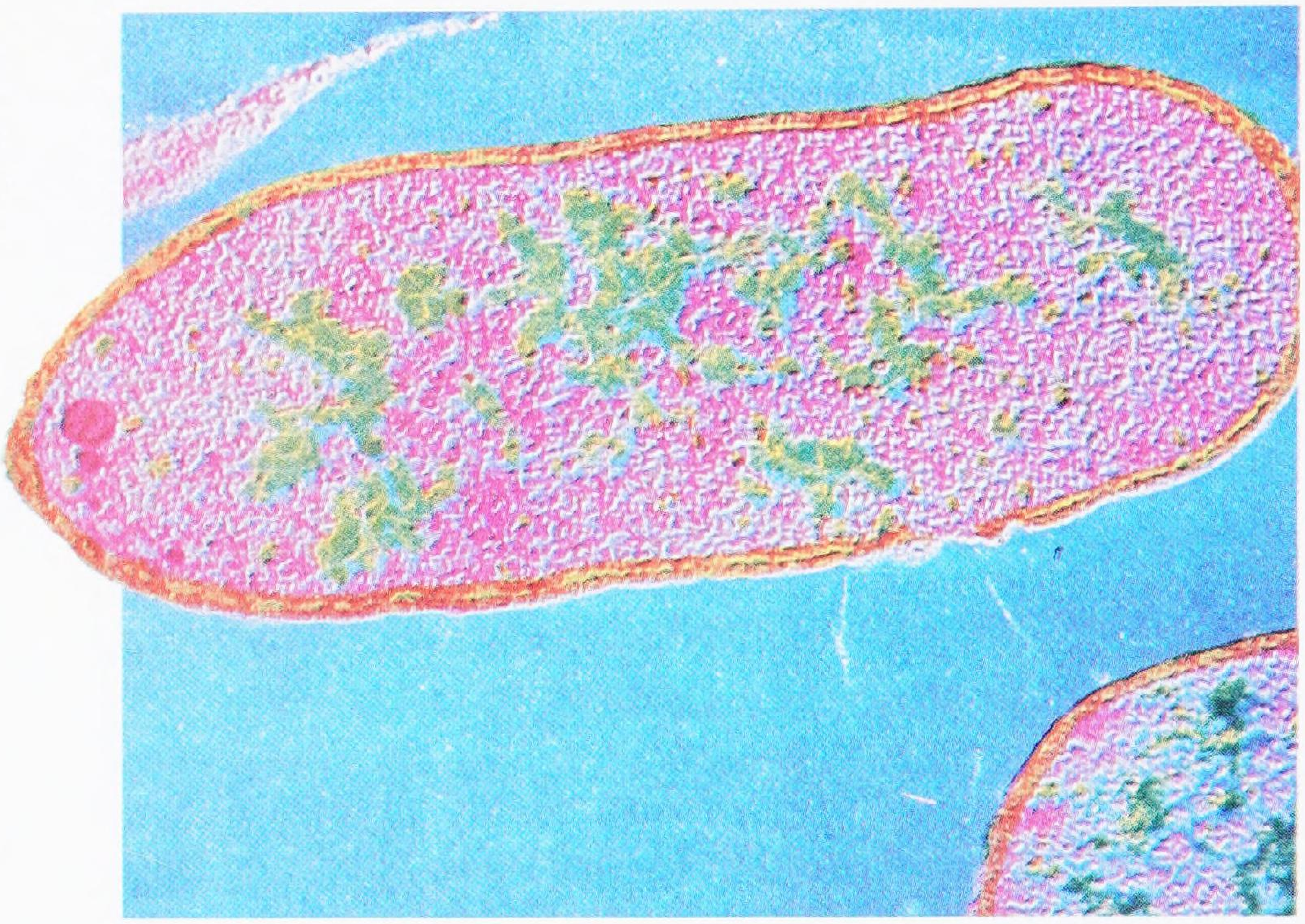


Figure 2-13. A bacterial cell is a one-celled prokaryotic organism. It has no membrane around its nuclear material. This type of bacterial cell lives in human intestines.

EcoTip

Cells need water to maintain health. Turning off the faucet every time you brush your teeth can conserve as much as five gallons of water that will benefit a living organism somewhere.

In contrast to plant and animal cells, bacterial cells are prokaryotic cells. Bacteria don't have membrane-covered organelles. In Figure 2-13, you can see the parts of a bacterial cell. It has a cell wall and cytoplasm, but it has only a single chromosome. There are no nuclei in bacteria, but they do contain ribosomes.

All cells have similar parts. Animal and plant cells have organelles. Bacterial cells have no membrane-covered structures.

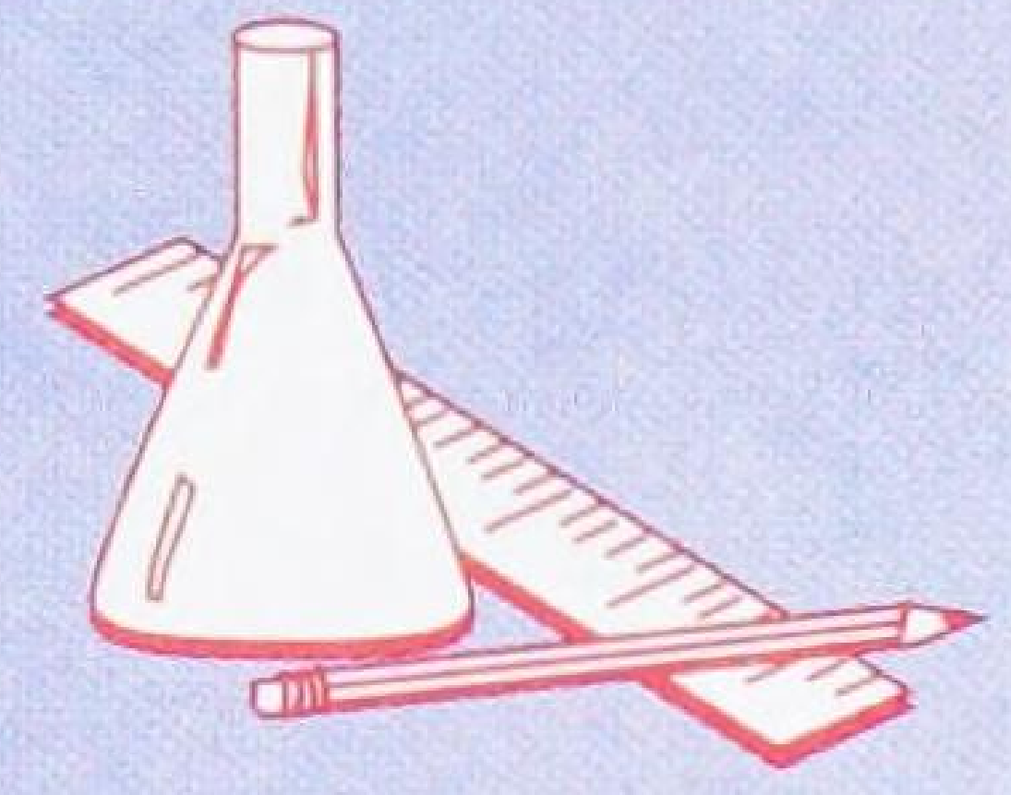
SECTION REVIEW

1. Diagram an animal cell and label its organelles.
2. Explain the importance of the cell nucleus in the life of a cell.
3. How are bacterial cells different from other cells?
4. **Apply:** Explain why you could be called a eukaryotic organism.
5. **Connect to Chemistry:** The cell is the smallest unit of living matter. Find out what the smallest unit of nonliving matter is.

Skill Builder

Comparing and Contrasting

Organize information about cell organelles in a table. Use this information to compare and contrast animal cells, plant cells, and bacterial cells. If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.



ACTIVITY 2-1

Comparing Plant and Animal Cells

Problem: *How do plant and animal cells differ?*

Materials

- microscope
- 1 microscope slide
- 1 coverslip
- forceps
- dropper
- *Elodea* plant
- prepared slide of human cheek cells

Procedure

1. Follow the directions in Appendix A on page 670 for use of low and high power objectives on your microscope and for making a wet-mount slide.
2. With forceps, remove a young leaf from the tip of an *Elodea* plant. Place it on a microscope slide. Add a drop of water and a coverslip.
3. Place the slide on the microscope stage and observe the leaf on low power. Focus on the top layer of cells. Draw what you see.
4. Carefully focus down through the top layer of cells to observe the layers of cells.
5. Focus on one cell. Observe the movement of chloroplasts along the cell membrane.
6. Observe the cell nucleus. It looks like a clear ball. Look at the nucleus on high power.
7. Make a drawing of the *Elodea* cell. Label the cell wall, cytoplasm, chloroplasts, and nucleus. Return to low power and remove the slide.
8. Place a prepared slide of cheek cells on the microscope stage. Locate the cells under low power.
9. Switch to high power and observe the cell nucleus. Draw and label the cell membrane, cytoplasm, and nucleus.

Analyze

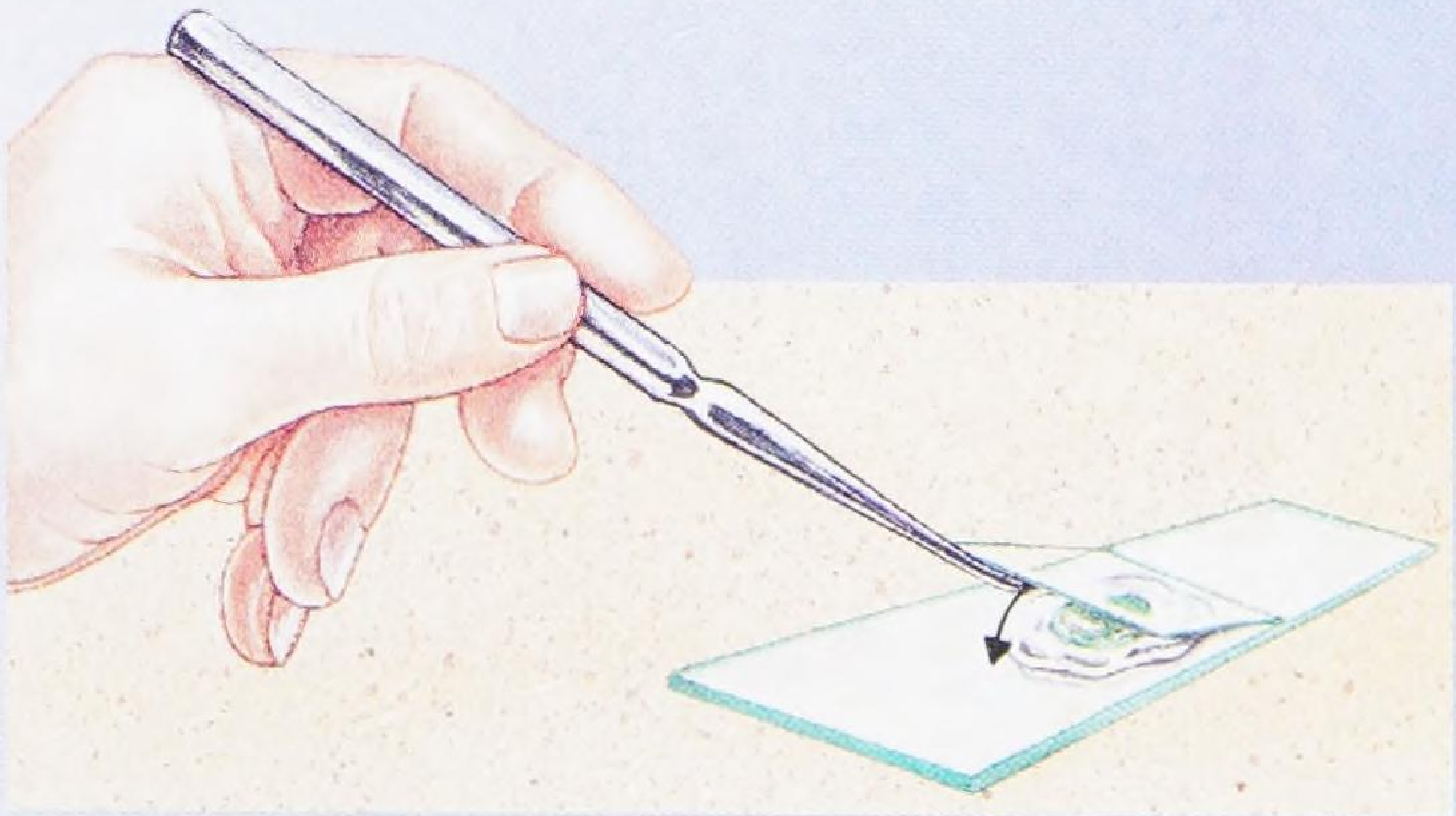
1. What parts of the *Elodea* cell were you able to identify?
2. How many cell layers could you see in the *Elodea* leaf?
3. Describe any movement you observed in the *Elodea* leaf.
4. What parts of the cheek cell were easy to identify?

Data and Observations

Cell Part	Elodea	Cheek
cytoplasm		
nucleus		
chloroplasts		
cell wall		
cell membrane		

Conclude and Apply

5. *Compare and contrast* the shape of the cheek cell and the Elodea cell.
6. Identify the cell part that determines the shape of a plant cell. An animal cell.
7. What can you conclude about the differences between plant and animal cells?



2-3 Cell Organization

New Science Words

tissues
organ
organ system

Objectives

- **Recognize that cells differ in size, shape, and function.**
- **Explain how cells of one-celled organisms differ from cells of many-celled organisms.**
- **Explain the differences among tissues, organs, and organ systems.**

How Cells Differ

Cells come in a variety of sizes. A single nerve cell in your leg may be a meter in length. A human egg cell, on the other hand, is no bigger than a dot on this *i*. Going a step further, a human red blood cell is about one-tenth of the size of a human egg cell.

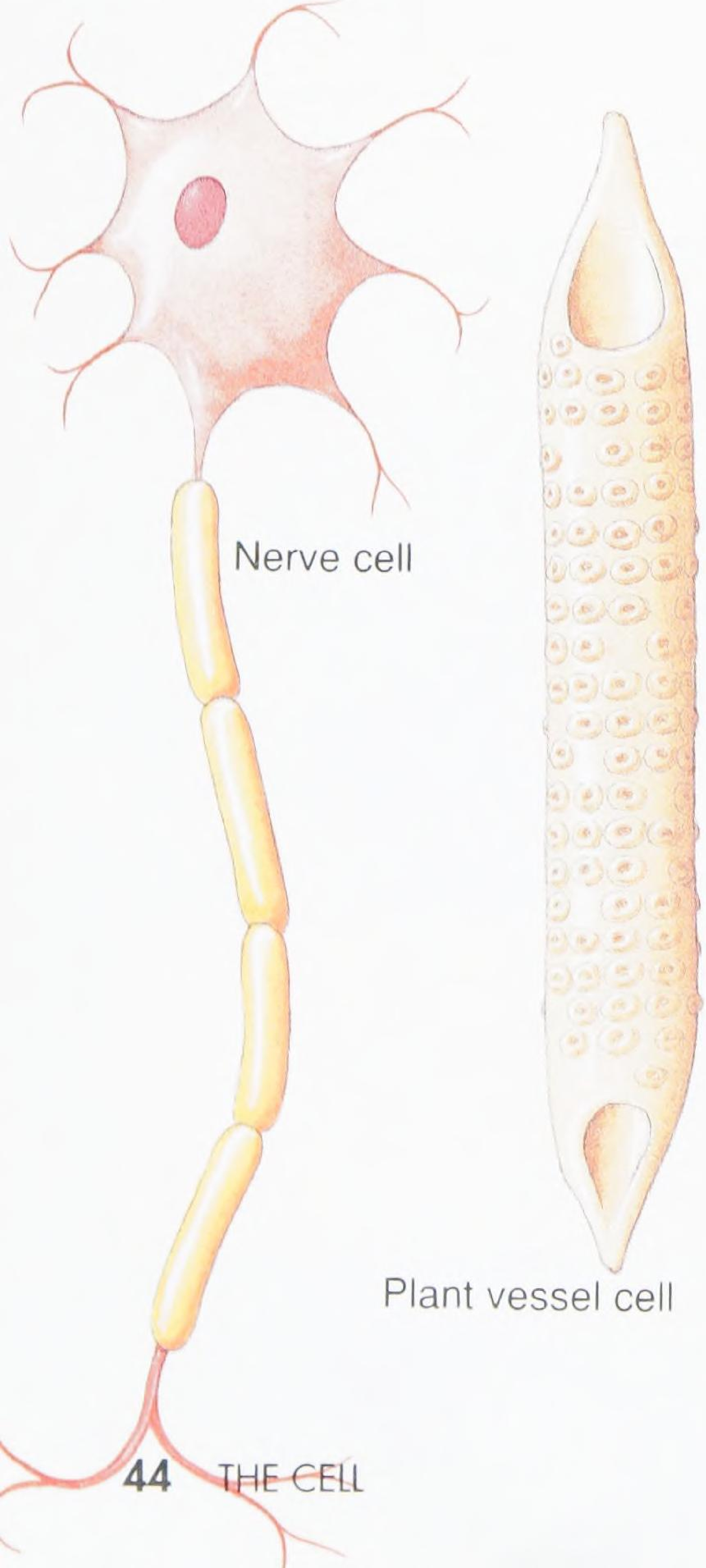
The shape of a cell may also tell you something about the job the cell does. The nerve cell in Figure 2-14 with its fine extensions sends impulses through your body. Look at its shape in contrast to the white blood cell, which can change shape. Some cells in its plant stems are long and hollow with holes. They transport food and water through the plant. Human red blood cells, on the other hand, are disk-shaped and have to be small and flexible enough to move through tiny blood vessels.

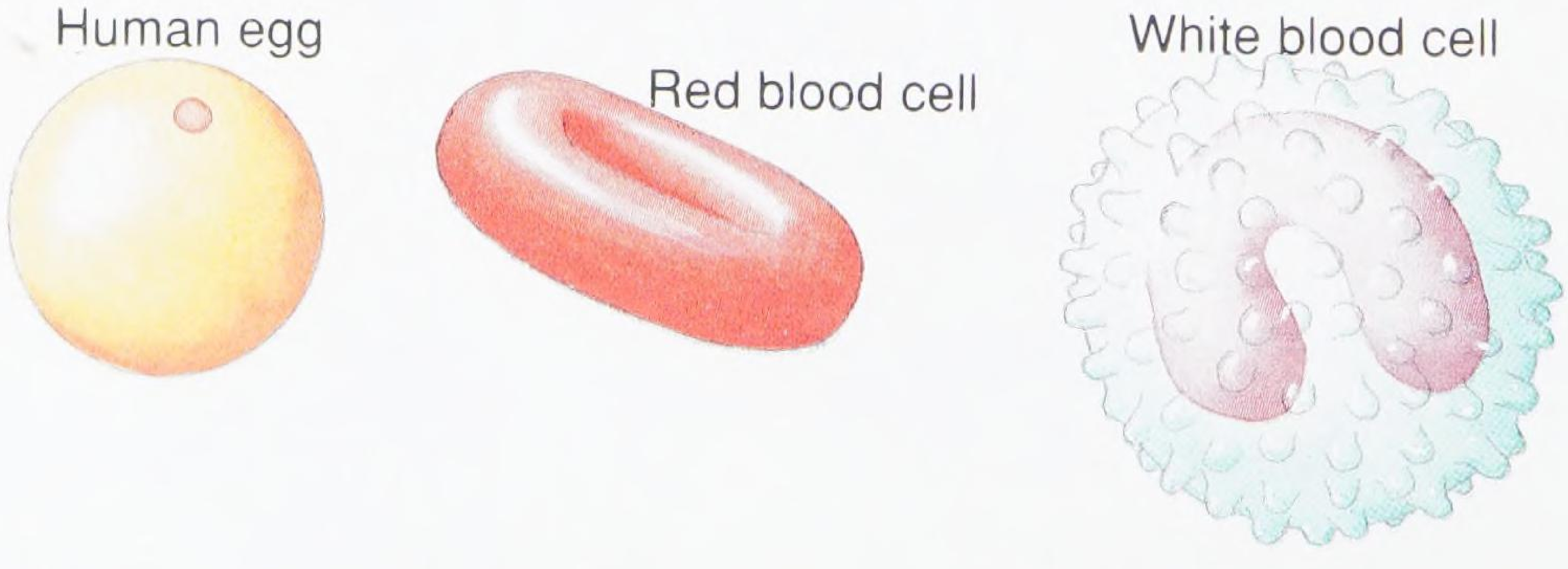
From Cell to System

A one-celled organism performs all its life functions by itself. Cells in a many-celled organism, however, do not work alone. Instead, each cell depends on other cells in some way as the organism carries out its functions. This interaction helps the whole organism stay alive.

In Figure 2-15 you can see a single plant cell. In Figure 2-15 you also see a group of the same type of plant cells that together form a tissue on the outside of a plant leaf.

Figure 2-14. Often the shape of a cell tells you something about the job it performs.





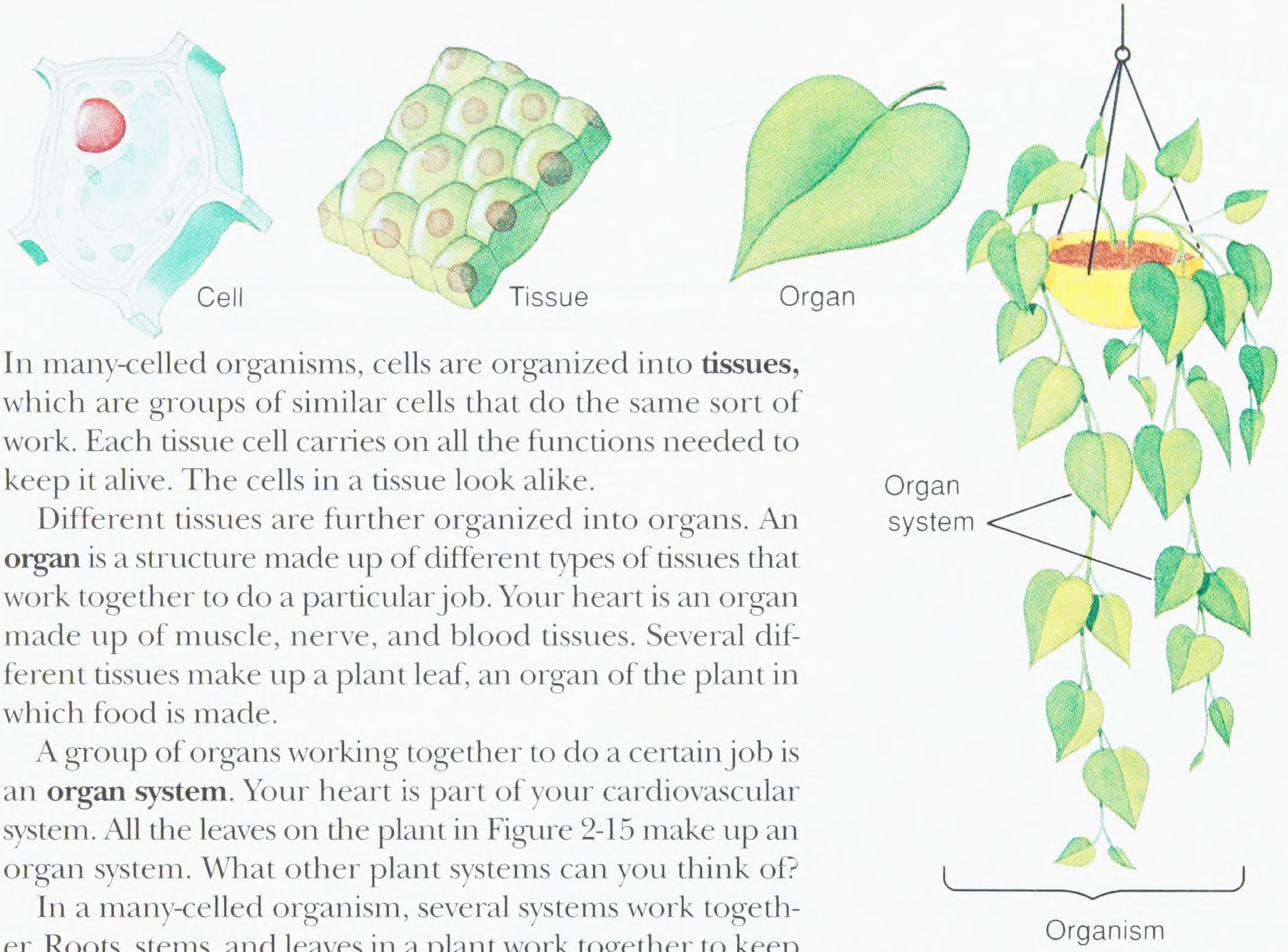


Figure 2-15. In a many-celled organism, different types of tissues are organized into organs, and systems.

In many-celled organisms, cells are organized into **tissues,** which are groups of similar cells that do the same sort of work. Each tissue cell carries on all the functions needed to keep it alive. The cells in a tissue look alike.

Different tissues are further organized into organs. An **organ** is a structure made up of different types of tissues that work together to do a particular job. Your heart is an organ made up of muscle, nerve, and blood tissues. Several different tissues make up a plant leaf, an organ of the plant in which food is made.

A group of organs working together to do a certain job is an **organ system**. Your heart is part of your cardiovascular system. All the leaves on the plant in Figure 2-15 make up an organ system. What other plant systems can you think of?

In a many-celled organism, several systems work together. Roots, stems, and leaves in a plant work together to keep the plant alive. Name three systems in your body.

Each cell in a many-celled organism carries on its own life functions. Although cells in an organism may differ in appearance and function, all the cells work together to keep the organism alive.

SECTION REVIEW

1. How is a tissue different from an organ system?
2. Give an example of an organ system in an animal and name the parts that make up the organ system.
3. **Apply:** How are cells of one-celled organisms different from those in many-celled organisms?
4. **Connect to Earth Science:** Systems are not just in living organisms. How does something like a solar system compare with a body of organ systems?

Interpreting Scientific Illustrations

Skill Builder

Use the diagram above to explain the levels of organization in living things. If you need help, refer to Interpreting Scientific Illustrations in the **Skill Handbook** on page 693.

SCIENCE & SOCIETY

2-4 Organ Transplants

New Science Words

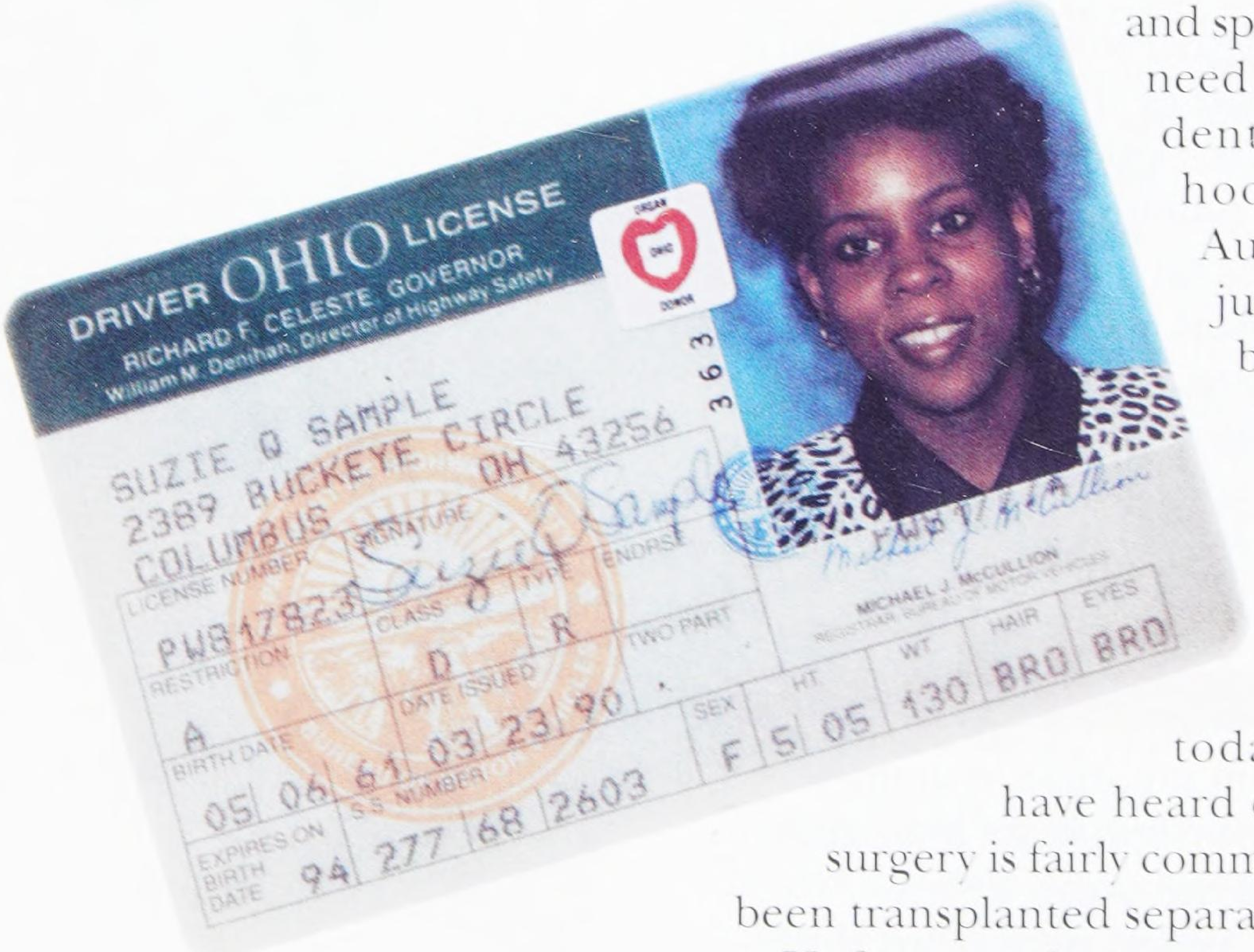
rejection

Objectives

- Relate the importance of science in your life.
- Discuss problems in organ transplants.

Spare Parts for Broken Hearts

Have you ever considered the thousands of things that take place in your body? Think of your body as an automobile. Mechanics are always busy replacing this belt, or that valve. The brakes, tires, battery, and spark plugs are all parts that often need to be changed. When an accident occurs, fenders, doors, or a hood may need to be replaced. Auto mechanics go to the local junkyard where usable parts can be recycled from cars that are no longer driveable. Who would have thought that a similar idea could someday be used to save lives?



DRIVER OHIO LICENSE
RICHARD F. CELESTE, GOVERNOR
William M. Denihan, Director of Highway Safety
ORGAN OHIO DONOR
363
SUZIE Q SAMPLE
2389 BUCKEYE CIRCLE
COLUMBUS OH 43256
LICENSE NUMBER PW817823
SIGNATURE Suzie Q Sample
CLASS D
TYPE R
ENDRSE
TWO PART
RESTRICTION A
DATE ISSUED 03 23 90
BIRTH DATE 05 06 61
SEX F
HT 5 05
WT 130
HAIR BRO
EYES BRO
S.S. NUMBER 277 68 2603
EXPIRES ON BIRTH DATE 94
Michael J. McCullion
MICHAEL J. McCULLION
REGISTRAR, BUREAU OF MOTOR VEHICLES

Organ transplants have become quite common in today's medical world. You may have heard of the kidney transplant. This surgery is fairly common. Hearts and lungs have also been transplanted separately and together.

Unfortunately, organ transplants are not always successful. Just as patients who receive blood transfusions must be matched with the donor's blood type, organs also must match. The human immune system, the network in our body that fights infections, is an eternal watchdog that attacks foreign invaders. This is to your advantage when the invader is a virus or bacteria. However, **rejection** is a process whereby the immune system attacks the transplanted organ because it is foreign to the body. Care must be taken to match the donor organs with the tissues of the person receiving the organ.

Drugs are given to turn down the body's immune system and keep rejection from happening. Antirejection drugs have greatly increased the success of transplant surgeries by keeping the immune system from attacking the new organ. However, the patient has to take antirejection drugs every day of his or her life.

Today, hearts, kidneys, livers, and other organs are transplanted. Doctors believe that someday, with more research, certain animals could be raised specifically to supply organs for human transplants. Yet other exciting ideas are being considered. For example, can one part of the body be used to replace another? Scientists have already constructed a heart for a dog using the muscle taken from the dog's back.

Where will technology end? Someday scientists may be able to grow new organs in the laboratory using organ tissue. We may each have our own spare organs on the shelf ready to fix our broken parts!

Figure 2-16. Cynthia Gonzales is able to run today because she received a healthy kidney from a donor.

SECTION REVIEW

1. Why have organ transplants become more successful?
2. Describe one problem with transplanting organs to humans.
3. **Connect to Physics:** Using what you know about cells, explain why it is beneficial for an organ that is being transplanted to be placed in cold storage until it is used.

SCIENCE & SOCIETY

You Decide!

Do you think that organs should be donated? Because there is such great demand for organs, but so few donors, some doctors are suggesting that donors be paid for their organs. Such an idea would make more organs available, but is it right to sell human body organs?

ACTIVITY 2-2

Comparing Plant and Animal Tissues

Problem: *How do tissues differ?*

Materials

- hamburger
- microscope slides (2)
- coverslips (2)
- dropper
- water
- microscope
- onion sections
- forceps
- iodine stain
- apron

Procedure

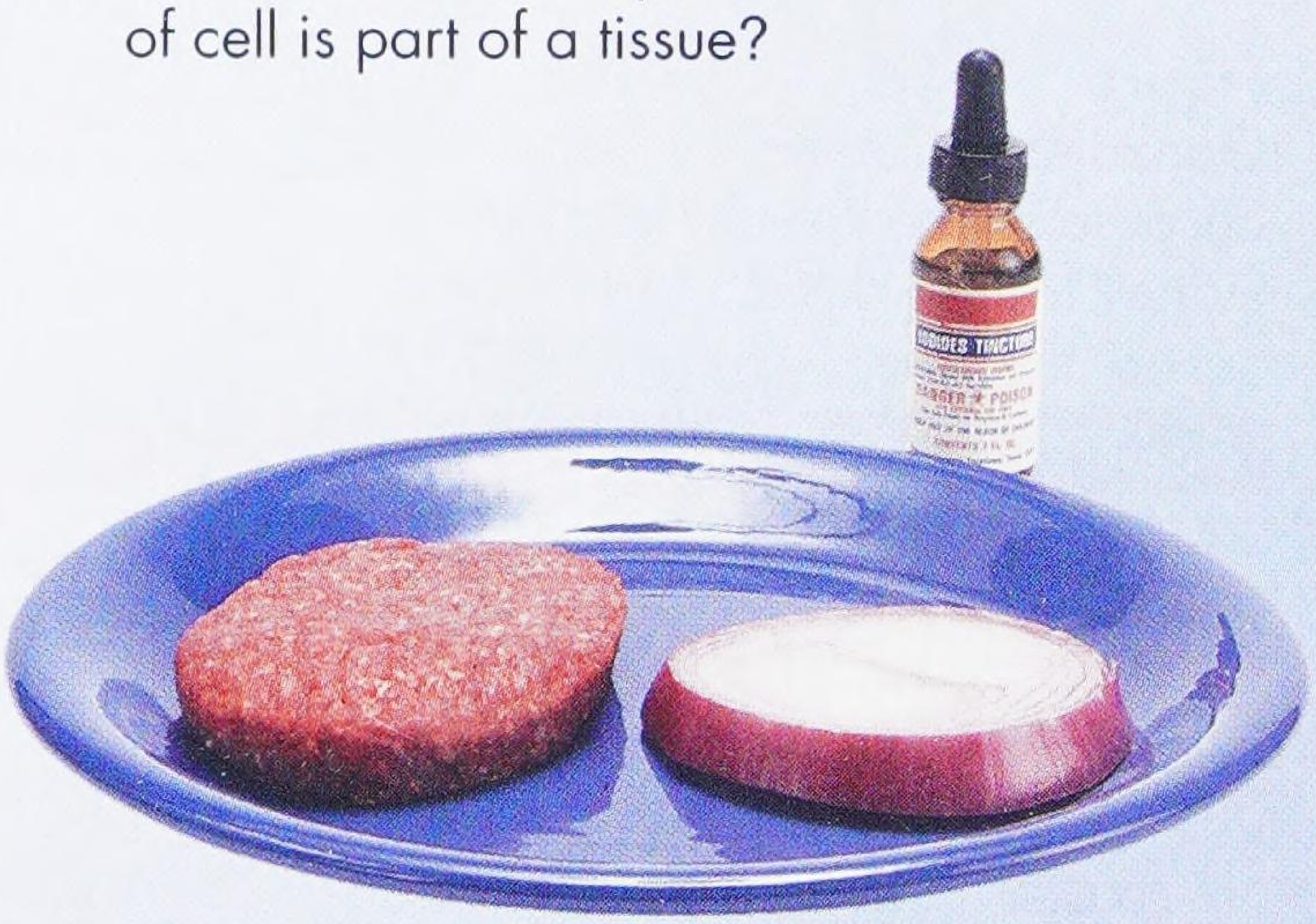
1. In your Journal, make a data table like the one shown.
2. Make a wet mount slide of a very thin piece of hamburger.
3. Place the slide on the microscope stage and focus on the cells using the low power objective. Turn to high power. Make a drawing of what you observe. Return to low power and remove your slide.
4. Use forceps to remove the thin membrane from inside a layer of onion. Make a wet mount slide of this membrane. Add a drop of iodine stain to the onion before adding the coverslip. **CAUTION:** *Iodine is poisonous and may burn your skin.*
5. Set the microscope on low power. Place the slide on the microscope stage and focus on the cells in the onion membrane using low power first.
6. Turn to high power. Make a drawing of what you observe. Return to low power and remove your slide.

Analyze

1. What is the shape of the cells in the hamburger tissue?
2. What is the shape of the cells in the onion membrane?
3. How many cell layers make up the tissue of the onion membrane?
4. What cell parts can you see in the onion cells?

Conclude and Apply

5. Describe how the onion tissue differs from the hamburger tissue.
6. What evidence do you have that each kind of cell is part of a tissue?



Data and Observations

Tissue	Observation	Description
hamburger		
onion		

CHAPTER REVIEW

SUMMARY

2-1: Cells: The Units of Life

1. Janssen made the first compound microscope in 1590. Leeuwenhoek used fine lenses to make accurate observations. Hooke, Schleiden, and Schwann all drew their conclusions about cells with the help of the microscope.

2. Compound light microscopes use light and lenses to make images. Electron microscopes bend beams of electrons in a magnetic field.

3. According to the cell theory, the cell is the basic unit of life. Organisms are made of cells and cells come from other cells.

2-2: Cell Structure

1. There are differences among animal, plant, and bacterial cells. Plant cells have cell walls and chloroplasts.

2. Cell functions are performed by organelles under control of DNA in the nucleus.

3. Prokaryotic cells do not have membrane-covered organelles; eukaryotic cells have membrane-bound organelles and a formed nucleus.

2-3: Cell Organization

1. Cells differ in size and shape. Shape is related to a cell's function.

2. One-celled organisms carry on all life activities within the single cell. Many-celled organisms may have tissues that perform separate functions.

3. Most many-celled organisms are organized into tissues, organs, and organ systems that perform specific jobs to keep an organism alive.

2-4: Science and Society: Organ Transplants

1. Through organ transplants, science works to provide ways to save lives.

2. Rejection and availability of matching organs are problems connected with organ transplants.

KEY SCIENCE WORDS

a. **cell membrane**
b. **cell theory**
c. **cell wall**
d. **chloroplasts**
e. **chromatin**
f. **compound light microscope**
g. **cytoplasm**
h. **electron microscope**
i. **endoplasmic reticulum**
j. **Golgi bodies**
k. **lysosomes**
l. **mitochondria**
m. **nucleus**
n. **organ**
o. **organelles**
p. **organ system**
q. **rejection**
r. **ribosomes**
s. **tissues**
t. **vacuoles**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. hereditary material in the nucleus
2. directs cell activities
3. where energy is generated for the cell
4. store food, water, or waste products
5. supports the plant cell
6. contain all the same kind of cell
7. where proteins are made
8. gel-like substance inside cell membrane
9. trap light energy in plant cells
10. package and secrete substances

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. A microscope that uses lenses and objectives to magnify is the _______.
   - **a.** compound light microscope
   - **b.** scanning electron microscope
   - **c.** transmission electron microscope
   - **d.** atomic force microscope
2. A microscope that magnifies parts inside a cell 300 000 times or more is the _______.
   - **a.** compound light microscope
   - **b.** stereoscopic microscope
   - **c.** transmission electron microscope
   - **d.** scanning electron microscope
3. The scientist who gave the name *cells* to structures he viewed was _______.
   - **a.** Hooke **c.** Schleiden
   - **b.** Schwann **d.** Virchow
4. A _______ is an organelle that can destroy old cell parts.
   - **a.** chloroplast **c.** lysosome
   - **b.** vacuole **d.** cell wall
5. According to _______, cells are the basic units of function and structure of all living things and come from cells that already exist.
   - **a.** Janssen
   - **b.** Hooke
   - **c.** Leeuwenhoek
   - **d.** Schleiden, Schwann, Virchow, and other scientists
6. A structure that allows only certain things to pass in and out of the cell is the _______.
   - **a.** cytoplasm **c.** cell wall
   - **b.** cell membrane **d.** nuclear envelope
7. Structures in the cytoplasm of the eukaryotic cell are called _______.
   - **a.** organs **c.** organ system
   - **b.** organelles **d.** tissues
8. Materials can move around inside the cell through the folded membranes of _______.
   - **a.** chromatin **c.** endoplasmic reticulum
   - **b.** cytoplasm **d.** Golgi bodies
9. A bacterial cell has _______.
   - **a.** a cell wall **c.** mitochondria
   - **b.** lysosomes **d.** a nucleus
10. Groups of different tissues form an _______.
    - **a.** organ **c.** organ system
    - **b.** organelle **d.** organism

USING LAB SKILLS

11. In the Mini-Lab on page 31, you saw how well objects are magnified with ordinary materials. Place a sheet of waxed paper over a word in your book. Then place the drop of water on the waxed paper over the word. Explain what you see. Is the drop concave or convex?
12. In the Mini-Lab on page 38, you made a model of cytoplasm. Use materials that resemble a cell and cell organelles to make a model of either a plant cell or an animal cell. Make a key to the cell parts to explain your model.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. How has the development of different microscopes helped scientists study cells?
14. Suggest a reason why a lysosome can exist inside a living cell without destroying the cell.
15. Explain why the cell theory is important.
16. What are some things to consider when an organ becomes available and a doctor has to decide between two patients?

APPLY

17. What type of microscope would be best to use to look at a piece of moldy bread? Give reasons to support your choice.
18. What would happen to a plant cell that suddenly lost its chloroplasts?
19. What would happen to an animal cell if it was missing ribosomes?
20. Choose two organelles of a plant cell and explain how they work together to help perform a life function.
21. How would you decide whether an unknown cell was an animal cell, a plant cell, or a bacterial cell?

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

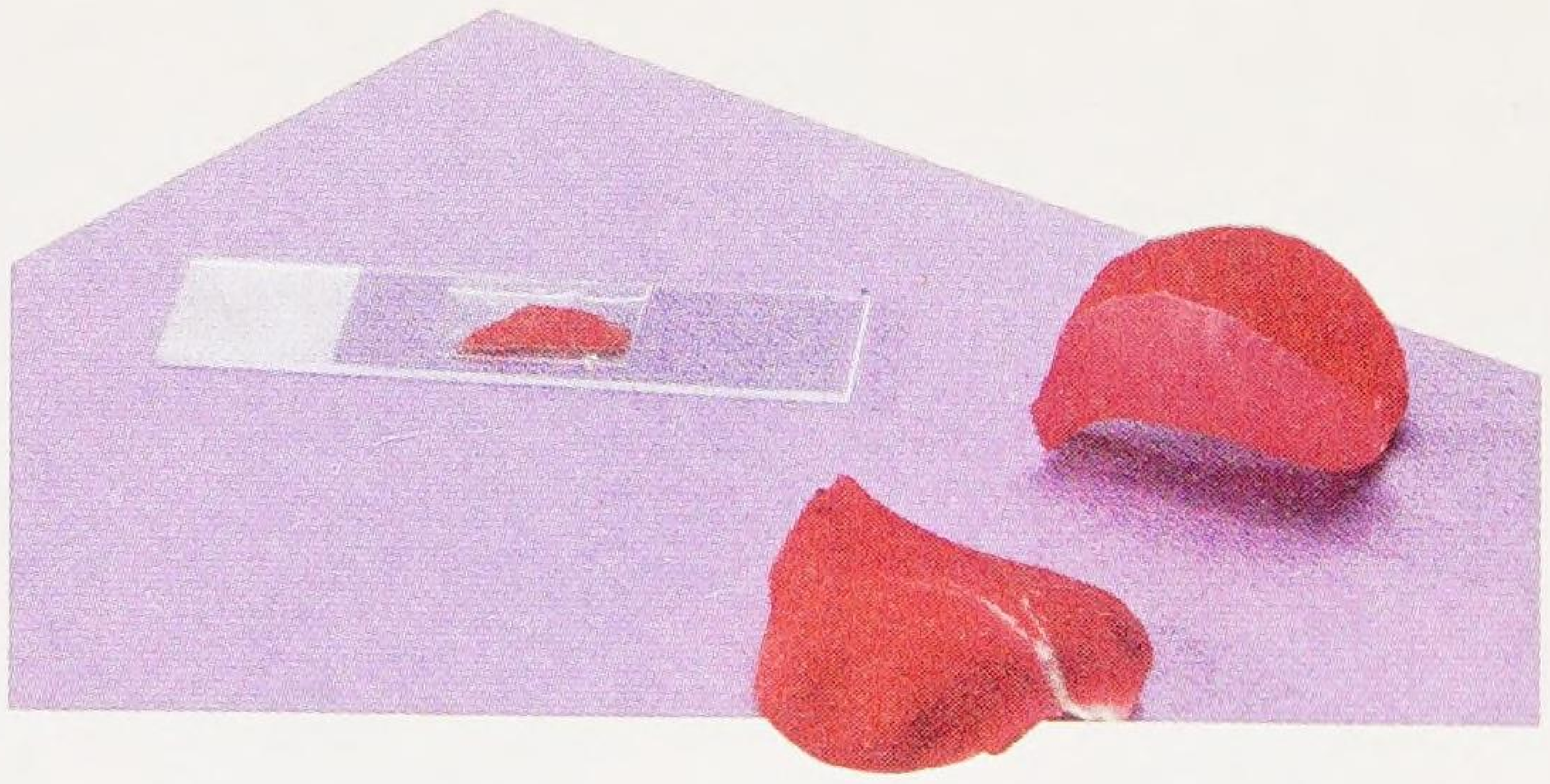
1. **Interpreting Scientific Illustrations:** Use the illustrations of cells on page 44 to describe how the shape of each cell is related to its function.
2. **Sequencing:** Sequence the major events and the scientists involved in the formation of the cell theory.
3. **Observing and Inferring:** Infer the effects of a damaged cell membrane on a cell.
4. **Making and Using Tables:** Make a table that lists the names of the cell structure(s) that are involved in each of the functions below. Structures may be listed in more than one column.

Function	Structures
Protection	
Movement of materials	
Breaking down substances	
Making substances	
Storing substances	

5. **Concept Mapping:** Use the list of events below to make a series of events concept map to show, in correct order, the cell structures involved in each step of making a protein.
   - packages proteins for movement outside of the cell
   - gives instructions to make proteins
   - allows packaged proteins to leave the cell
   - receives instructions and is the place where proteins are made

PROJECTS

1. Using the directions for Activity 2-1 (page 43), observe cells in a flower petal or tomato skin. Write a report based on your observations. Illustrate your report.
2. As a class project, turn the classroom into a model of a plant cell so that students and desks are within the "cell." Begin to consider what activity is like inside a real cell.



CHAPTER

3

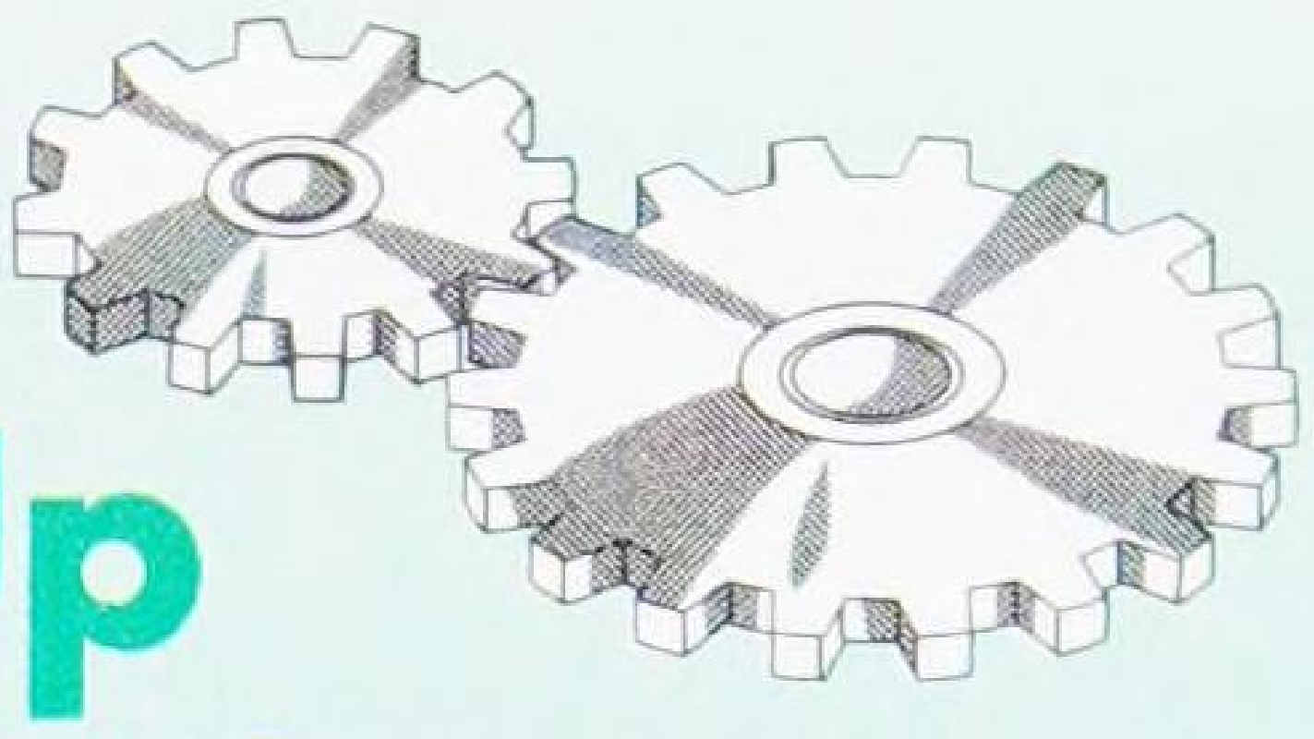
Cell Processes

You may have washed dishes or stayed in a pool so long that your fingers became wrinkled. What caused your fingers to wrinkle? How long did it take your fingers to return to normal? Why does this happen?

FIND OUT!

Do this simple activity to find out why your fingers wrinkle.

Pour 250 mL of water into each of two small bowls. Stir 15 g of salt into one of the bowls of water. Label it salt water. Place slices of raw potato into each bowl. *Predict* how the potato slices will be affected. After 20 minutes, pick up the slices and examine them. Describe the slices. How does this compare with wrinkled fingers?



Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 3-1 Chemistry of Living Things
- The Nature of Matter
- The Chemistry of Life

Section 3-2 Cell Transport
- Diffusion and Osmosis
- Other Kinds of Transport

Section 3-3 Energy in Cells
- Trapping Energy for Life
- Releasing Energy for Life

Section 3-4 Science and Society
Nonbiodegradable Materials in Your Environment
- Recycling and the Environment

Previewing Science Skills

- In the **Skill Builders,** you will make and use tables, make a concept map, and compare and contrast.
- In the **Activities,** you will measure, use tables, conclude, and infer.
- In the **MINI-Labs,** you will observe and experiment.

What's next?

What you've just seen is the effect of water moving into and out of the potato cells. You will learn how atoms, molecules, and compounds relate to the movement of materials into and out of cells. You will also study which organisms produce food and how organisms use food as a source of energy.

3-1 Chemistry of Living Things

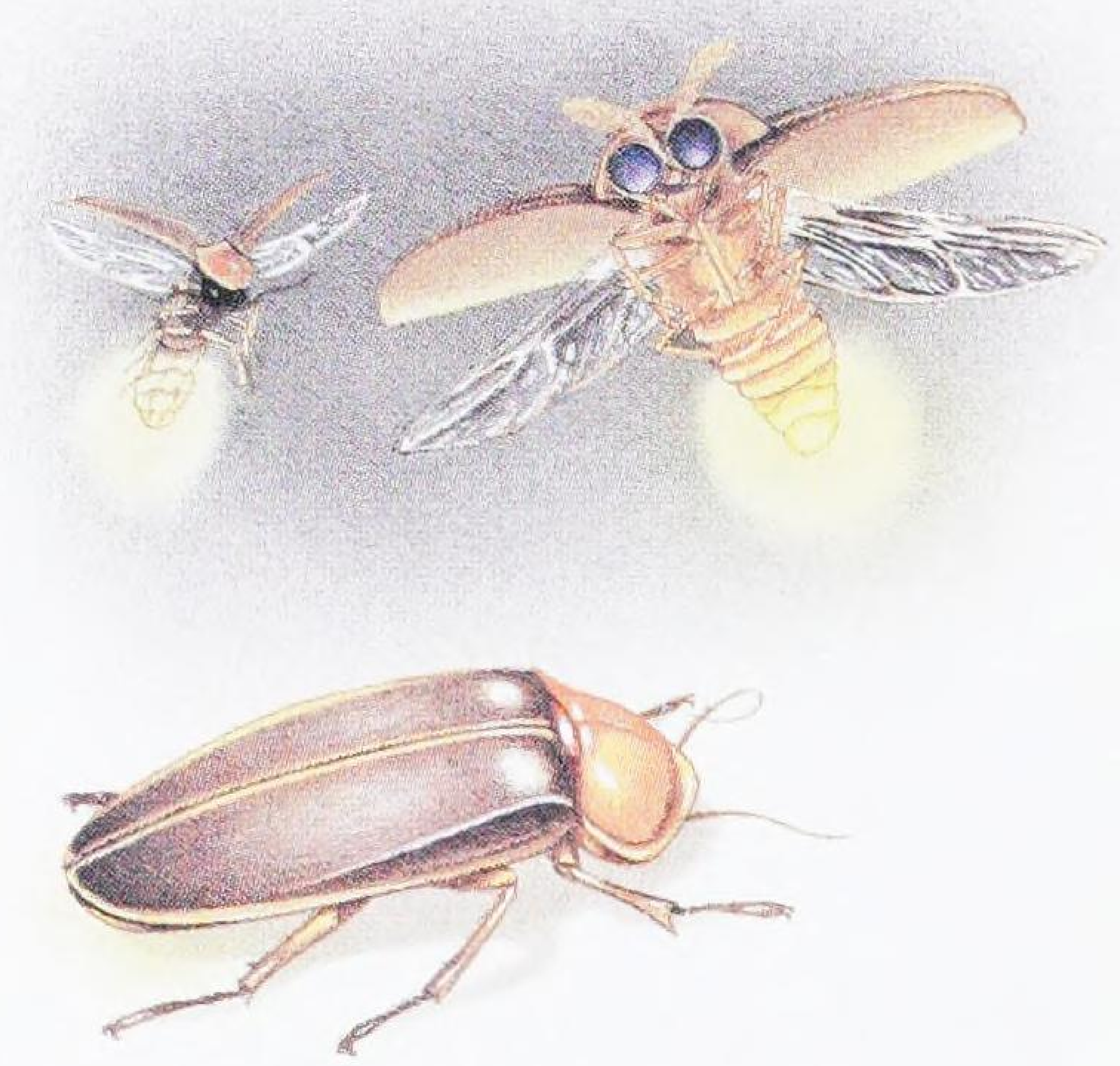
New Science Words

carbohydrates
lipids
proteins
enzymes
nucleic acids

Objectives

- Describe differences among atoms, elements, molecules, and compounds.
- Recognize the relationship between chemistry and life science.
- Compare inorganic and organic compounds.

The Nature of Matter



Do you know what makes up the universe? If you ask a scientist, he or she will probably say "matter and energy." Matter is anything that has mass and takes up space. How many things can you think of that fit that category?

Everything is made up of matter. You are made of matter and so are the fireflies on this page. Even the air that they fly through is made up of matter. Matter exists in the form of small units called atoms. Figure 3-1 shows a model of an oxygen atom. At the center of the atom is a nucleus, which contains two kinds of particles, protons and neutrons. A proton has a positive charge, and neutrons have no charge. Electrons are particles found outside the nucleus. They are negatively charged.

What about the energy that the scientist mentioned? Energy in the universe is wrapped up in bonds that hold atoms together. When fireflies blink and shine in the dark, they release some of that energy in the form of light. To release this energy, the atoms that were bound together had to be broken apart. A chemical reaction took place.

When something is made up of only one kind of atom, it is called an element. An element can't be broken down into any simpler form. The element oxygen (O_2) is made

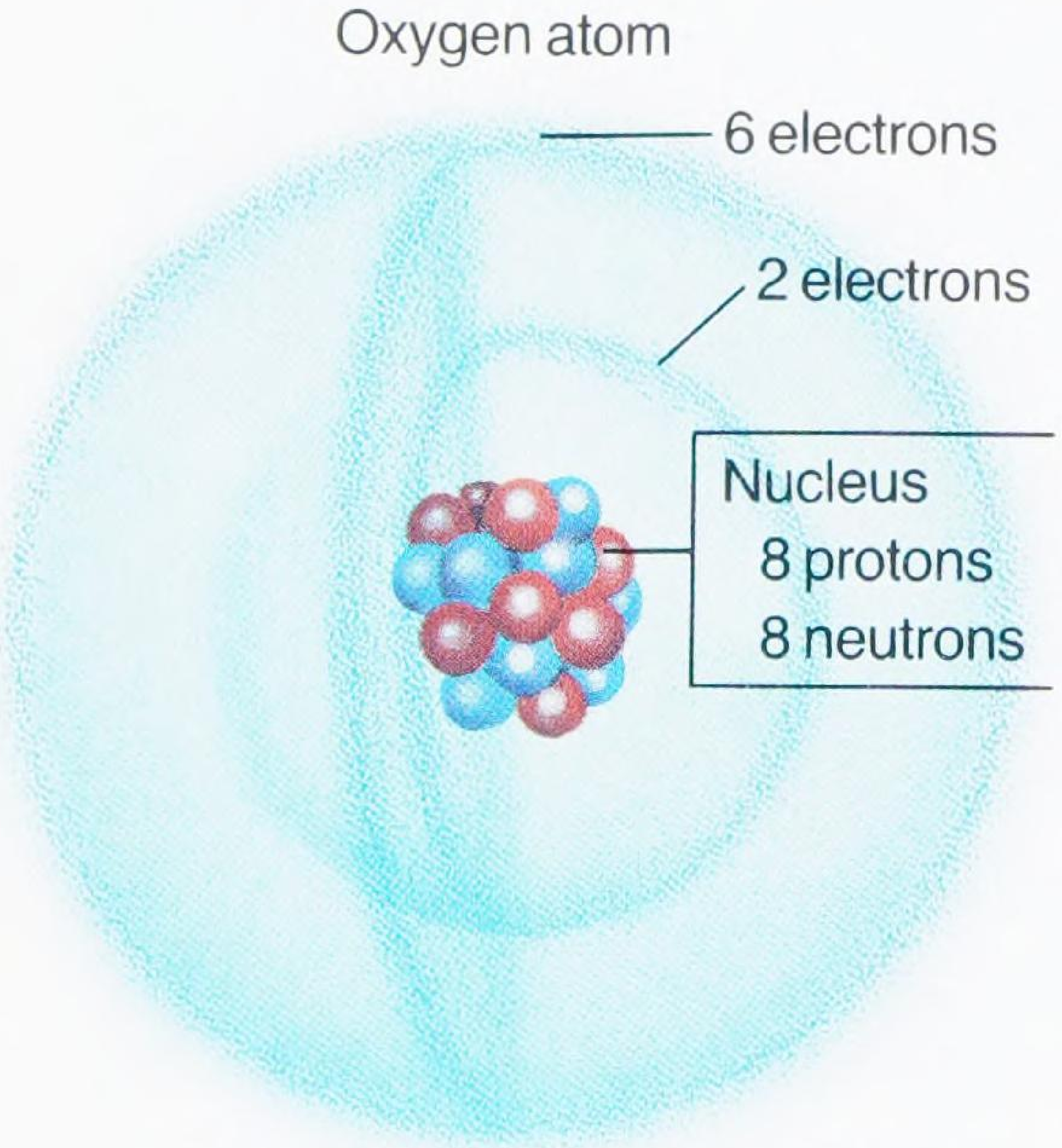


Figure 3-1. An Oxygen atom model shows the placement of electrons, protons, and neutrons.

Table 3-1

ELEMENTS THAT COMPOSE THE HUMAN BODY

Symbol	Element	Percent
O	Oxygen	65.0
C	Carbon	18.5
H	Hydrogen	9.5
N	Nitrogen	3.3
Ca	Calcium	1.5
P	Phosphorus	1.0
K	Potassium	0.4
S	Sulfur	0.3
Na	Sodium	0.2
Cl	Chlorine	0.2
Mg	Magnesium	0.1

up of only oxygen atoms, and hydrogen (H_2) is made up of only hydrogen atoms. Each element has its own symbol. More than 92 elements occur naturally on Earth. Everything, including you, is made of one or a combination of these elements. Table 3-1 lists elements as they occur in the human body. What are the two most common elements in your body?

When atoms of two or more elements are joined, or bonded together, a compound is formed. For example, water is made of the elements hydrogen and oxygen, as shown in Figure 3-2. In water, there are two atoms of hydrogen for every atom of oxygen. The chemical formula for water is H_2O. A chemical formula shows the kind and number of atoms that form a compound. The formula represents a single molecule of a compound. A molecule is the smallest part of a compound with all the properties of that compound. Glucose, the major form of sugar used by cells for energy, is a compound. It is made of the elements carbon, hydrogen, and oxygen, and its formula is $C_6H_{12}O_6$.

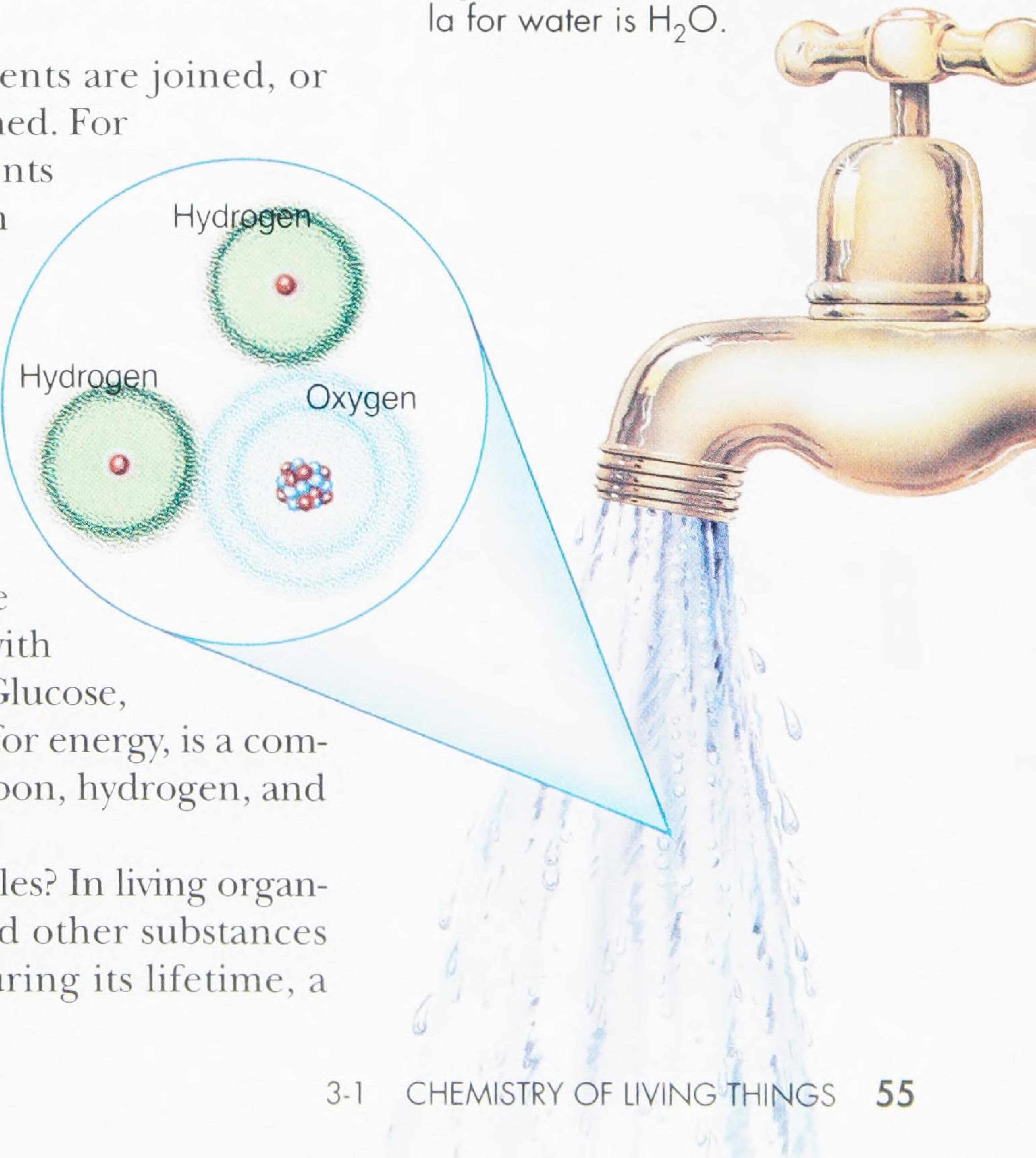


Figure 3-2. The chemical formula for water is H_2O.

What is so important about molecules? In living organisms, cell membranes, cytoplasm, and other substances are all in the form of molecules. During its lifetime, a

Figure 3-3. All organisms are dependent on water for life.

cell will put together and break apart many molecules to build new cell parts and supply itself with energy. Many of these molecules are found in solution in cytoplasm. A solution is a mixture in which one or more substances mix evenly with other substances. When you dissolve salt in water, you get a salt solution. You've probably noticed the taste of salt when you perspire. That's because your cells are bathed in a salt solution. Living organisms also have suspensions. A suspension is a mixture in which substances spread through a liquid or gas, then settle out over time. Your blood is a suspension. If a test tube of blood is left undisturbed, the red blood cells and white blood cells will gradually settle to the bottom. Of course, blood in your body is moved constantly by the pumping action of your heart. Therefore, the cells don't settle out.

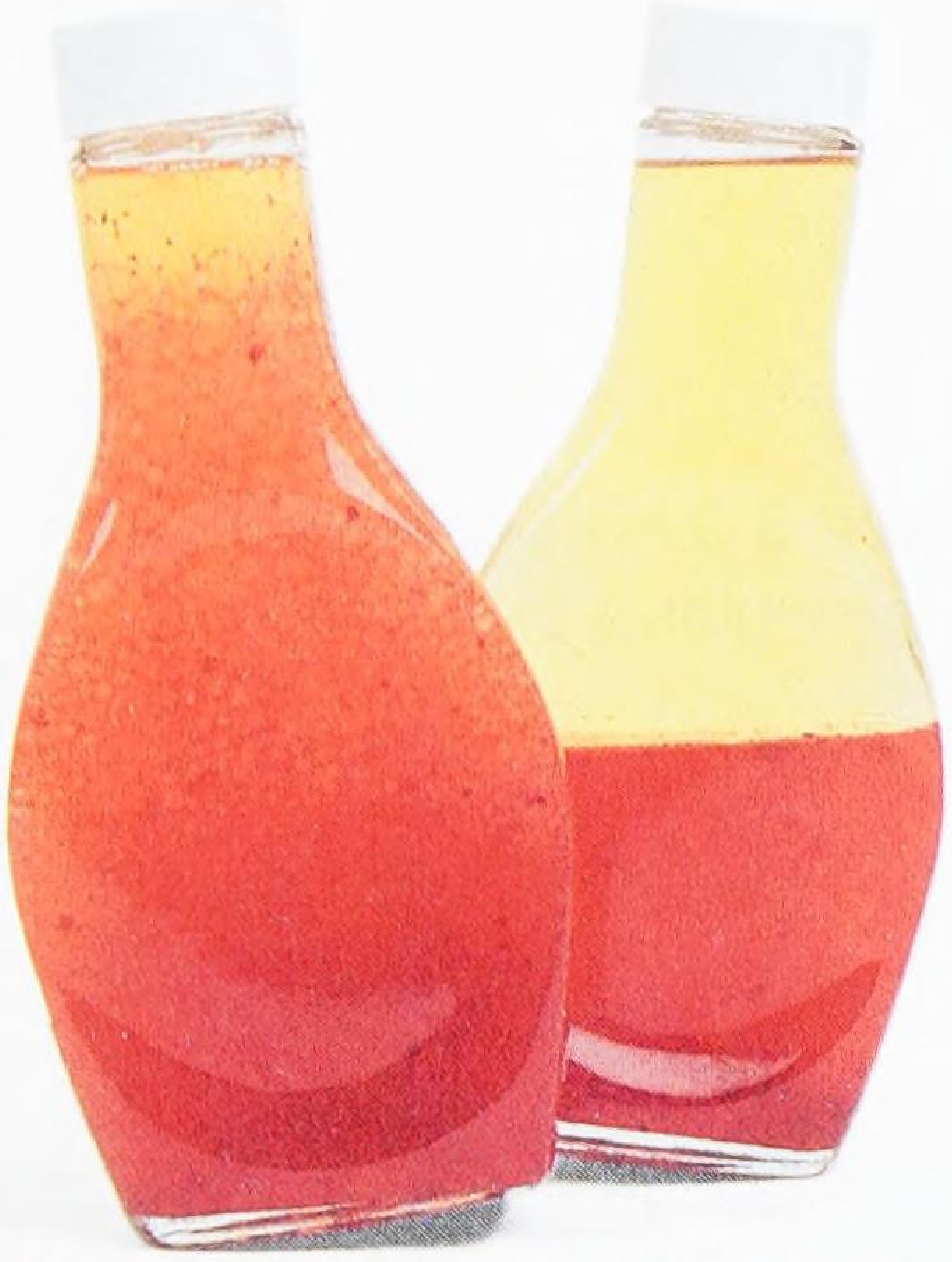


Figure 3-4. Some salad dressings are suspensions. Large pieces separate and fall to the bottom after the dressing stands awhile.

Connect to... Earth Science

In Earth's crust are silicon 27.7%, aluminum 8.1%, iron 5%, calcium 3.6%, sodium 2.8%, potassium 2.6%, and magnesium 2.1%. *Compare* these elements with those in the human body.

The Chemistry of Life

Compounds in living organisms are classified into two groups, organic and inorganic. Organic compounds contain carbon. Organic compounds make up some foods and membranes in cells. Inorganic compounds are made from elements other than carbon.

Water, an inorganic compound, makes up a large part of living matter. It is, therefore, one of the most important compounds in living things. In order for substances to be used in cells, they have to be dissolved in water. Nutrients and waste materials are carried throughout your body in solution form.

Four groups of organic compounds make up all living things. These are carbohydrates, lipids, proteins, and nucleic acids. **Carbohydrates** are organic compounds made up of carbon, hydrogen, and oxygen. Sugars, starch, and cellulose are carbohydrates. By breaking down

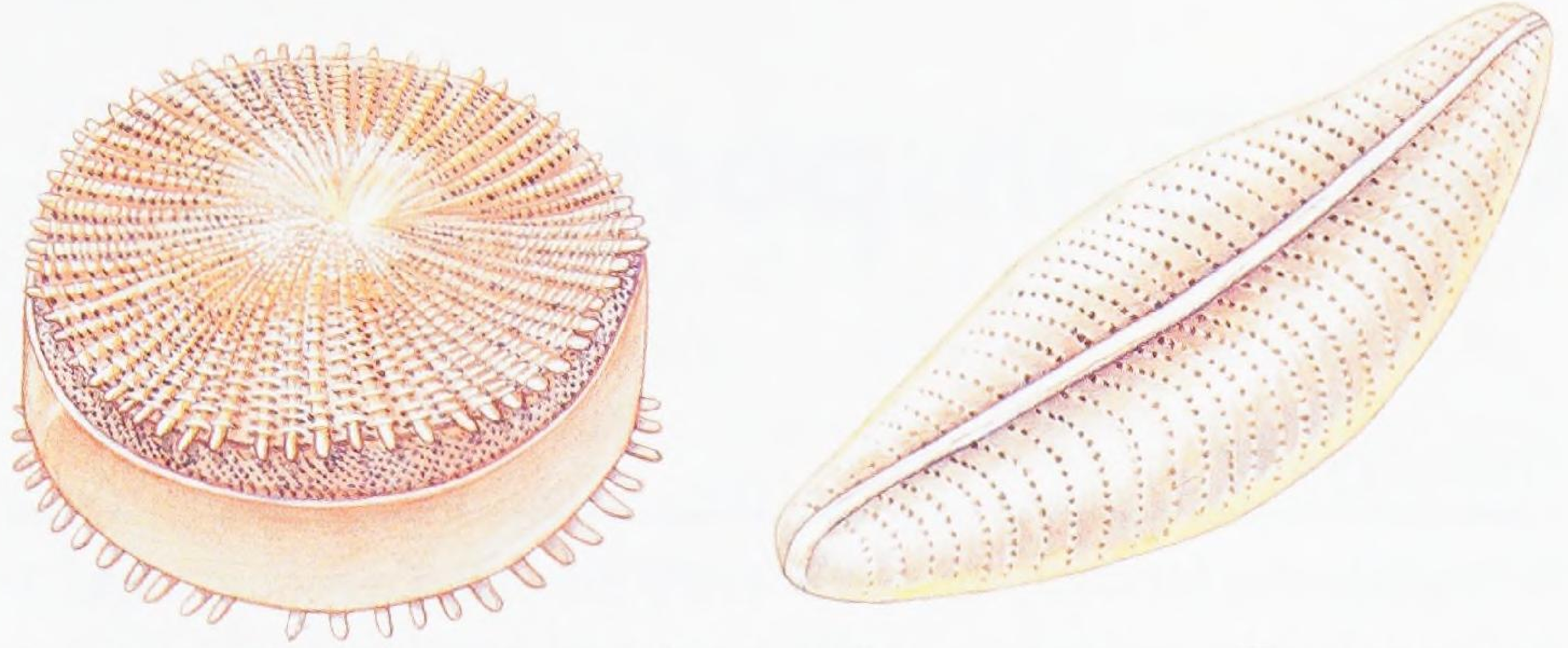


Figure 3-5. Some organisms, such as diatoms, store oils instead of carbohydrates as sources of energy.

these molecules, organisms release energy. The energy is then used to power cell processes.

Carbohydrates supply energy, but **lipids** are organic compounds that store and release even larger amounts of energy. In Chapter 2 you learned that cell membranes are made up of two layers of lipids. Fats, oils, and waxes are types of lipids found in different organisms.

Proteins, the third group of organic compounds, are used for building cell parts. Protein molecules are scattered throughout cell membranes. Proteins are made up of smaller molecules called amino acids. Certain proteins called **enzymes** (EN zimez) speed up chemical reactions in cells without being changed. Enzymes take part in all the chemical reactions in cells.

Nucleic acids are large organic molecules that store important information in cells. One nucleic acid, DNA, is found in chromosomes, mitochondria, and chloroplasts. It carries information that directs each cell's activities. A second nucleic acid, RNA, carries information for making proteins and enzymes in cytoplasm.

MINI-Lab

How do enzymes work?

Fill a test tube with milk. Crush a rennin tablet and add the crushed tablet to the milk. Rennin is an enzyme. Let the milk stand during your class period. *Observe* what happens to the milk. *Infer* how the action of rennin on milk might be useful.

SECTION REVIEW

1. How are atoms different from molecules?
2. Why is water important to living organisms?
3. How do organic and inorganic compounds differ?
4. **Apply:** Diatoms are one-celled organisms that store oils instead of carbohydrates. How do they benefit from these oils?
5. **Connect to Chemistry:** Find out what the Periodic Table is and what it is used for.

In Your JOURNAL

In a table **in your Journal**, classify the foods you eat in a day as carbohydrates, lipids, or proteins. *Calculate* the percentage of your diet each represents for that day.

Skill Builder

Making and Using Tables

Use Table 3-1 on page 55 to analyze what elements make up more than 98 percent of the human body. If you need help, refer to Making and Using Tables in the **Skill Handbook** on page 690.

3-2 Cell Transport

New Science Words

passive transport
active transport
diffusion
equilibrium
osmosis
endocytosis
exocytosis

Objectives

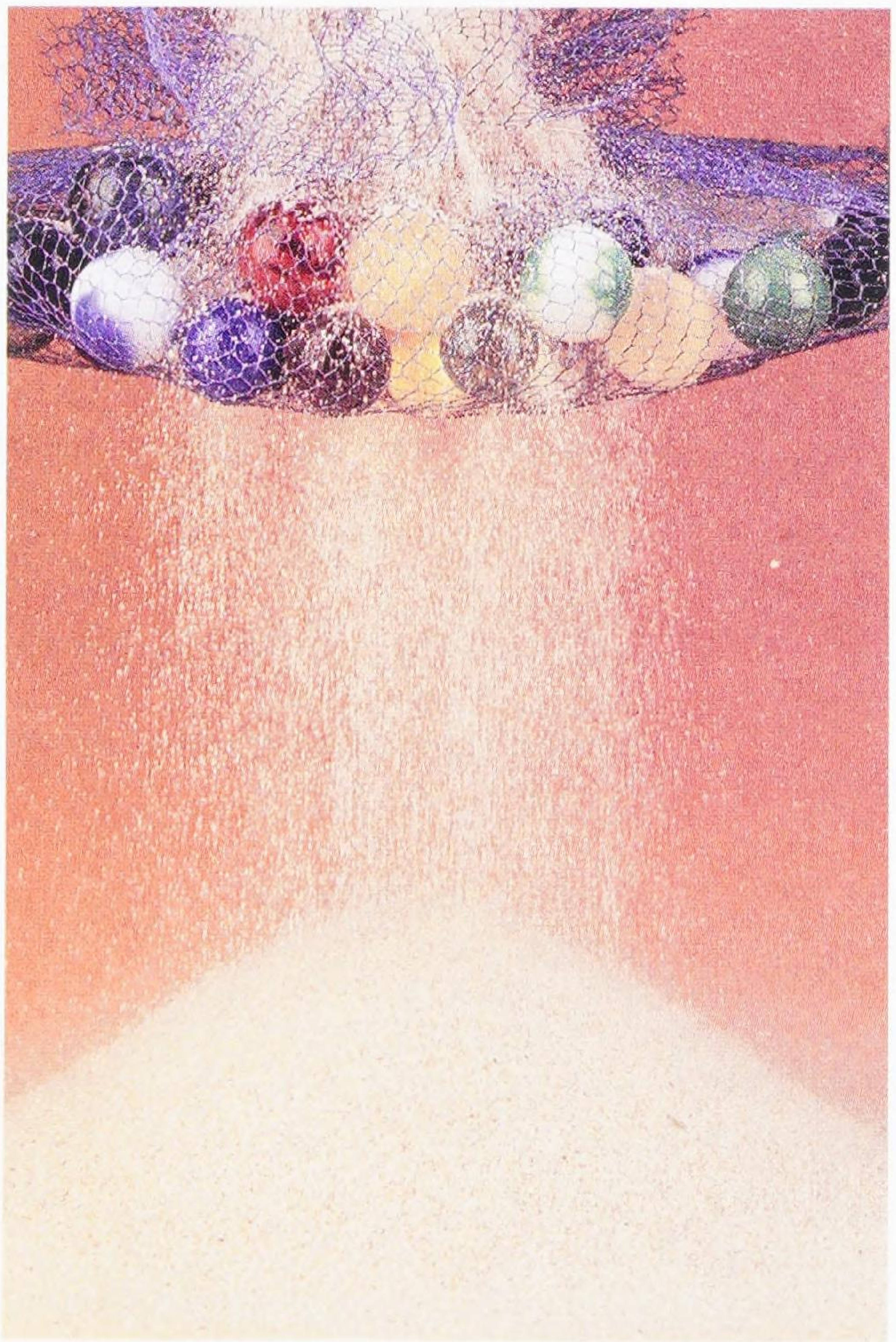
- Explain the function of a selectively permeable membrane.
- Describe the processes of diffusion and osmosis.
- Compare and contrast passive transport and active transport and give examples of each.

Diffusion and Osmosis

Cells obtain food, oxygen, and other substances from their environment. They also release waste materials. If a cell has a membrane around it, how do these things move into and out of the cell? How does the cell control what enters and leaves?

Have you ever seen marbles in a mesh bag? Although the mesh bag has holes in it, the marbles stay inside because they are larger than the holes. If you put sand in with the marbles, the sand will fall right through the holes because sand grains are smaller than the holes. The mesh bag is said to be selectively permeable because it allows some things to pass through it but not others. The marbles and sand are models for molecules. The cell membrane is selectively permeable. It allows some molecules to pass through but not others.

Figure 3-6. A cell membrane, like a mesh bag, will let some things through more easily than others.



If materials move through a cell membrane without the help of energy, **passive transport** takes place. If materials require energy to move through a cell membrane, **active transport** takes place.

Passive transport depends on the fact that molecules in solids, liquids, and gases move about. Molecules move constantly. As they move, they move from places where they are crowded together into places where there are fewer of them. One type of passive transport is **diffusion,** the movement of molecules from an area where there are many to an area where there are few.

Molecules diffuse in liquids and in gases. You experience diffusion when someone opens a bottle of perfume in a closed room.

Drop a sugar cube into a glass of water and taste the water. Then taste it again in three or four hours, the next day, and the next week. At first, the sugar molecules are concentrated near the sugar cube in the bottom of the glass. Then very slowly, the sugar molecules diffuse throughout the water until they are more evenly distributed. When the molecules of a substance are spread evenly throughout a space, a state called **equilibrium** occurs. But molecules don't stop moving when equilibrium is reached. They continue to move, and equilibrium is maintained.

You may remember that water makes up a large part of living matter. The passive transport of *water* through a cell membrane by diffusion is called **osmosis.** Osmosis is important to cells because they are surrounded by water molecules and they contain water molecules. Water molecules move from where they are in large numbers to where they are in small numbers. When the number of water molecules inside and outside the cell is the same, a state of equilibrium is reached.

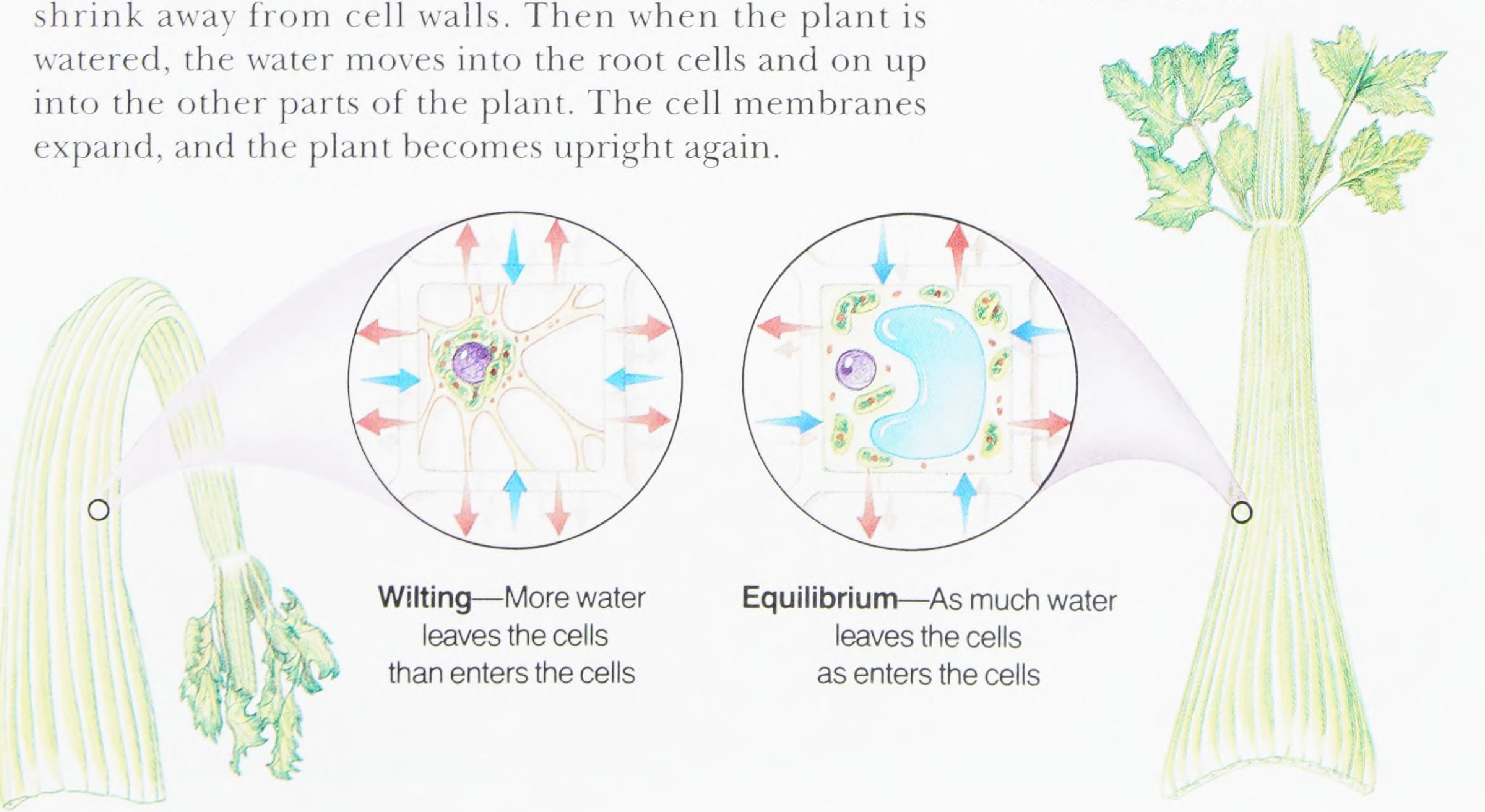
If you become extremely thirsty, you may say that you feel dehydrated. If cells don't have the water that they need, they dehydrate, or lose water. If you forget to water a plant, it will soon wilt. There is less water in the soil around the roots. Therefore, water tends to move out of the root cells. The cells in the rest of the plant don't get supplied with water from the roots. Cell membranes shrink away from cell walls. Then when the plant is watered, the water moves into the root cells and on up into the other parts of the plant. The cell membranes expand, and the plant becomes upright again.

MINI-Lab

How does temperature affect the rate of diffusion of molecules?
Prepare beakers with equal amounts of cold water and hot tap water. Add one antacid tablet to each AT THE SAME TIME. *Predict* which will dissolve faster. Observe and record how long it takes for the tablet to dissolve in each beaker. Explain any differences you observe.

What is equilibrium?

Figure 3-7. Lack of water eventually causes a plant to wilt because more water diffuses from the cells than enters.



Wilting—More water leaves the cells than enters the cells

Equilibrium—As much water leaves the cells as enters the cells

Other Kinds of Transport

Cells take in a variety of substances. Some, like glucose molecules, are so large that they enter the cell only with the help of protein carrier molecules in the cell membrane. Each carrier molecule helps to move only one type of molecule through the cell membrane. Glucose molecules are too large to move quickly across the cell membrane, so carrier molecules help speed up their movement. Carrier proteins use energy when moving molecules into and out of a cell. Therefore, carrier molecules are involved in active transport.

Sometimes cells have to move substances from where there are small amounts to where there are larger amounts. This process is the opposite of diffusion. It requires energy and is a type of active transport. An example of this type of active transport can be seen when plant root cells take in minerals. These cells need minerals from the soil, and there are already more minerals in the root cells than in the water around the roots. The cells use energy to move additional minerals into the root cells. In your body, wastes are moved by active transport out of some kidney cells.

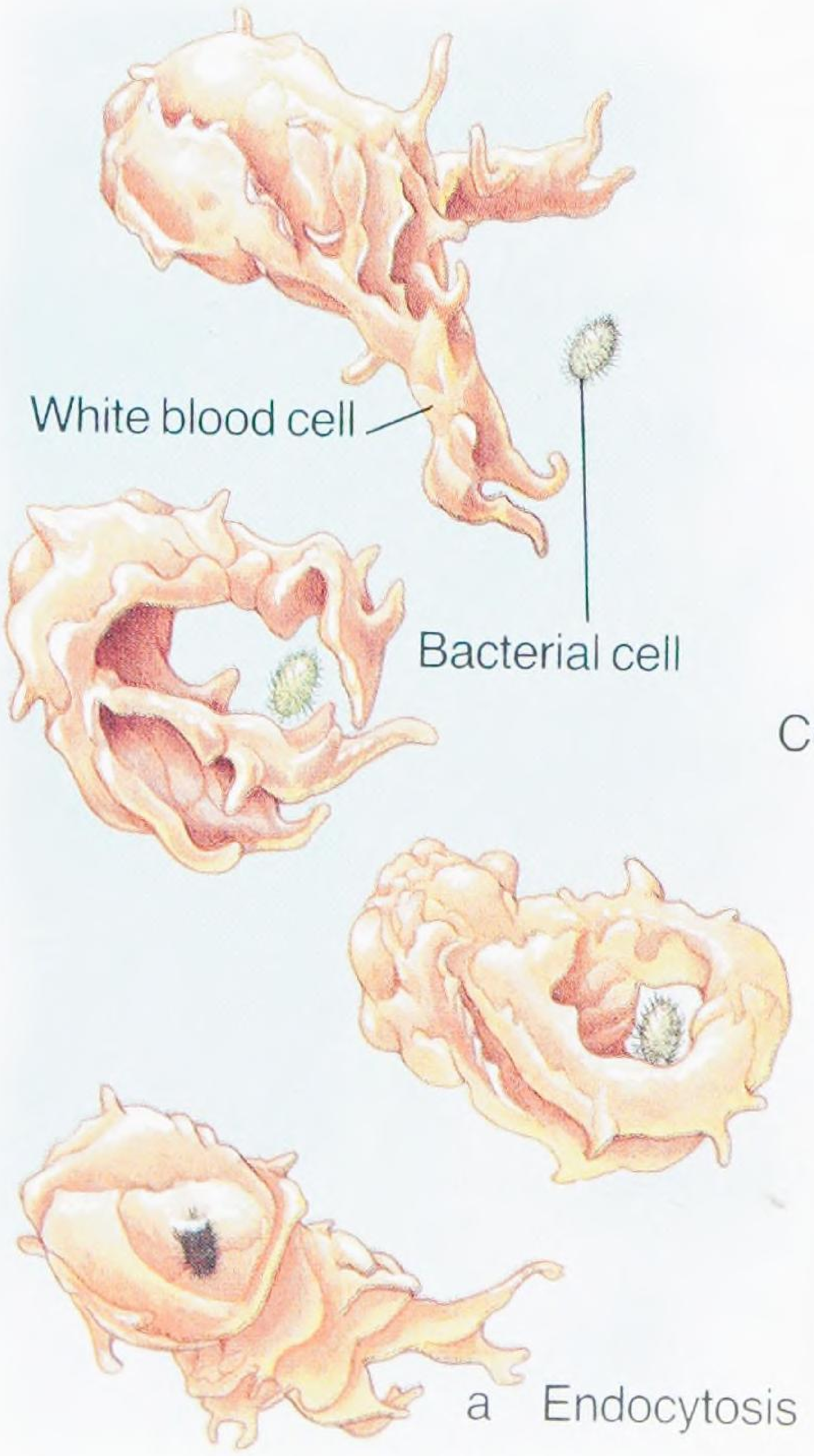
Some substances are too large to pass through the cell membrane by passive or active transport. Large protein molecules and bacteria enter the cell by becoming enclosed in a part of the membrane that folds in to form a sac. The sac pinches off and goes into the cytoplasm in a process called **endocytosis.** In the opposite way, wastes in vacuoles or proteins packaged by Golgi bodies move to the cell membrane. The package fuses with the cell membrane, and its contents are released from the cell in a process called **exocytosis.**

Connect to...

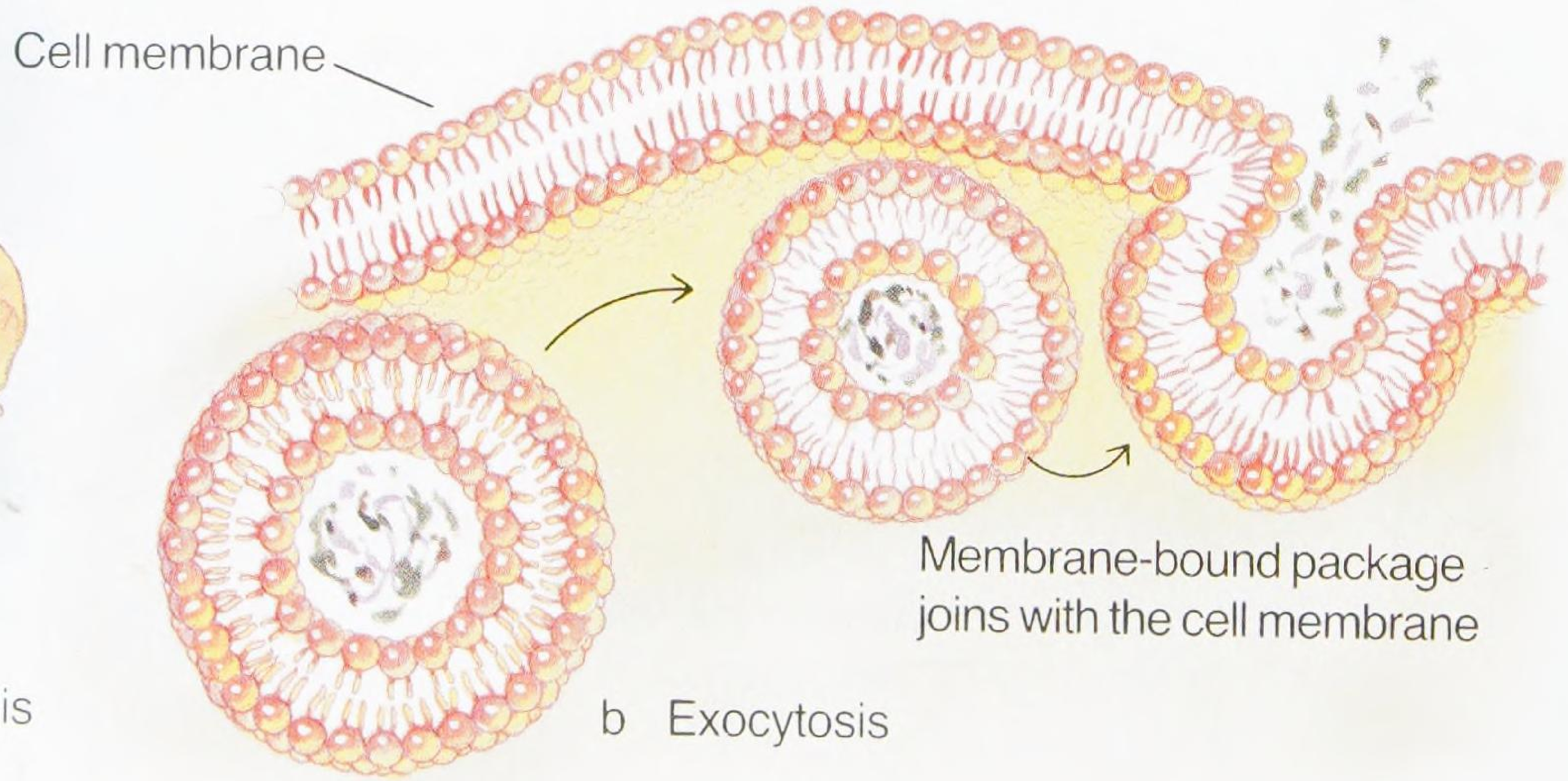
Physics

Repeat the Find Out experiment on page 53. Using what you now know about osmosis and diffusion, *infer* what took place in the potato left in salt water.

Figure 3-8. A white blood cell uses endocytosis to engulf a bacterial cell (a). In exocytosis, substances in small sacs are released at the cell membrane (b).



a Endocytosis



b Exocytosis

PROBLEM SOLVING

What Happened to the Salad?

Lucy made a salad of lettuce, tomatoes, carrots, and cucumbers. She seasoned the salad with herbs, salt, and pepper. Then she placed it in the refrigerator for a couple of hours.

When Lucy returned, she took the salad from the refrigerator. The lettuce had wilted, and the other vegetables were limp. She noticed that there was liquid in the bottom of the bowl. Where did the liquid come from?

Think Critically: Why had the lettuce wilted?

Cells have to stay in balance with their environment. Cells keep this balance, called homeostasis, by controlling what enters and leaves the cells through passive and active transport. You can see that the selectively permeable cell membrane and its transport systems are important in keeping cells and organisms alive and healthy.

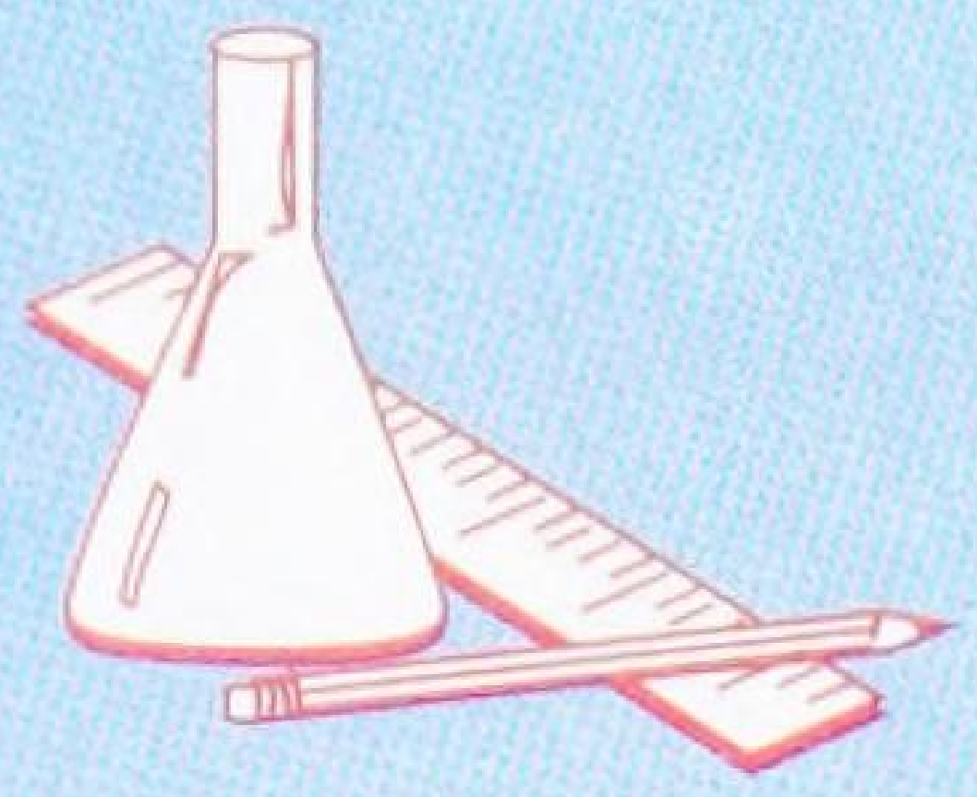
SECTION REVIEW

1. In what way are cell membranes selectively permeable?
2. Compare and contrast osmosis and diffusion.
3. How do active and passive transport differ?
4. How does a cell take in large bacterial cells?
5. **Apply:** Why are fresh fruits and vegetables sprinkled with water in produce markets?
6. **Connect to Physics:** Compare diffusion of perfume in a warm room and a cold room.

Concept Mapping

Skill Builder

Make a network tree concept map to use as a study guide to help you tell the difference between passive transport and active transport. Begin with the phrase *Transport through membranes.* If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.



ACTIVITY 3-1

Observing Osmosis

Problem: *How does osmosis occur in an egg?*

Materials

- raw eggs in shells (2)
- 600-mL beakers with lids (4)
- white vinegar (600 mL)
- distilled water (900 mL)
- 20% salt solution (900 mL)
- graduated cylinder

DISTILLED WHITE
VINEGAR
16 FL OZ (1 PT) 473mL
100
90
80
70
60
50

Procedure

1. Place one egg in each of two beakers labeled A and B. Cover each egg with white vinegar. *Observe* the eggs after 30 minutes.
2. After 24 hours, observe the eggs. Record your observations. Pour the vinegar off each egg and rinse with plain water.
3. Add 300 mL of distilled water to the egg in beaker A.
4. Add 300 mL of 20% salt solution to the egg in beaker B. *Predict* what will happen to each egg.
5. On the third day, carefully remove the egg from beaker A. *Measure* and record the volume of distilled water in the beaker. Discard the distilled water and add 300 mL of fresh distilled water. Return the egg to the beaker.
6. Remove the egg from beaker B. *Measure* the salt water remaining. Record the amount in the data table. Discard the salt water, and add 300 mL of fresh salt water to the beaker. Return the egg to the beaker.
7. On the fourth day, repeat Steps 5 and 6.
8. On the fifth day, repeat Steps 5 and 6. Then give the eggs to your teacher for disposal.

Analyze

1. What did you observe after 30 minutes?
2. After 24 hours, what did you observe?
3. What happened to the size of the egg in distilled water? In salt water?

Conclude and Apply

4. Does the egg membrane allow everything to move in and out? Explain your answer.
5. Explain why water was able to move into one of the eggs. Which egg?
6. *Infer* why water moved out of one of the eggs. Which egg?
7. What can you conclude about how osmosis occurs in an egg?

Data and Observations

Day	1	2	3	4	5
Salt water volume					
Observations					
Distilled water volume					
Observations					

Energy in Cells

3-3

Objectives

- Explain the difference between producers and consumers.
- Compare and contrast the processes of photosynthesis and respiration.
- Describe how cells get energy from glucose through the process of fermentation.

New Science Words

metabolism
producers
consumers
photosynthesis
cellular respiration
fermentation

Trapping Energy for Life

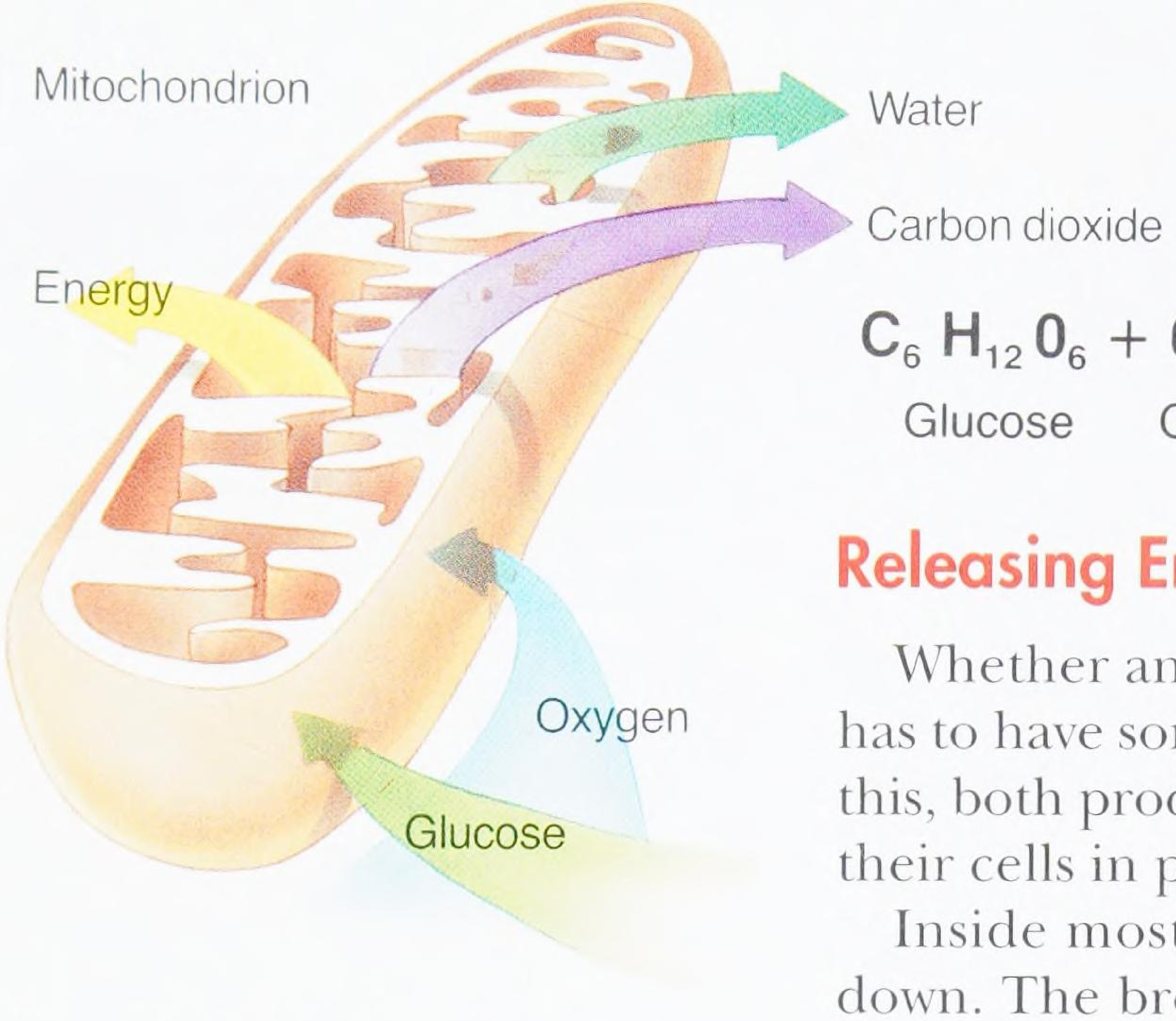
Think of all the energy used in a basketball game. Where do the players get all that energy? The simplest answer is, “from the food they eat”. Cells take chemical energy stored in food and change it into other forms of energy that can be used in metabolism (muh TAB uh lihz um). **Metabolism** is the total of all activities of an organism that enable it to stay alive, grow, and reproduce.

All living things are divided into two groups based on how they obtain their food energy. These two groups are producers and consumers. Organisms that make their own food, such as plants, are called **producers.** Organisms that can’t make their own food are **consumers.** Producers change light energy into chemical energy by a process called **photosynthesis** (foht oh SIHN thuh sus). During photosynthesis, the energy from sunlight is used to make glucose from carbon dioxide (CO_2) and water. During this process oxygen is also given off. Plants and other producers use a green pigment called chlorophyll found in chloroplasts. Therefore, photosynthesis in green plants takes place in the chloroplasts. Producers use some of the glucose they make during photosynthesis for energy. The rest is stored.

Do you eat vegetables? Have you ever watched sheep graze? Consumers eat producers such as vegetables and take in the stored energy. Consumers also eat other consumers in order to get energy. These relationships form a food chain. Producers are at the beginning of every food chain.

Figure 3-9. Green plants are producers because they use sunlight, carbon dioxide, and water to produce chemical energy in the form of glucose.

What is the difference between a producer and a consumer?



$$C_6 H_{12} 0_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + \text{Energy}$$

Glucose Oxygen Carbon dioxide Water

Figure 3-10. Respiration releases carbon dioxide, water, and energy. In what way do these products remind you of photosynthesis?

Releasing Energy for Life

Whether an organism is a producer or a consumer, it has to have some way to release energy from food. To do this, both producers and consumers break down food in their cells in processes called **cellular respiration**.

Inside most cells, glucose is the food that is broken down. The breakdown process takes place within mitochondria. This breakdown uses oxygen that you take in as you breathe.

During respiration, oxygen combines with glucose to release stored energy. The energy is released in a series of steps. Carbon dioxide and water are given off as waste

TECHNOLOGY

Biodegradable Plastics

Discarded plastics make up 32 percent of the garbage produced in the United States. Most of this plastic lasts forever. To reduce waste, scientists are working on plastics that can be broken down naturally.

One current method of breaking down plastic is to build molecules of cornstarch into the plastic. Cornstarch breaks down in nature, so the plastic is at least broken into smaller pieces. However, most of these plastic products are only 6 to 8 percent cornstarch, so the remaining plastic pieces are still large. Some scientists predict they will soon be able to produce plastics with a 50 percent cornstarch content.

A second method to help solve the plastic garbage problem involves the use of plastics produced by bacteria. Some soil bacteria are known to produce natural plastics and store them to use as energy sources. By changing factors such as temperature and food sources for the bacteria, scientists can adjust the characteristics of the plastic produced.

Think Critically: What is the advantage of bacterial plastics over plastic-cornstarch mixtures?

BIODEGRADABLE PLASTIC BAG
BIODEGRADABLE PLASTIC BAG

products. Some of the energy produced in respiration is stored, and some of the energy is lost as heat.

Sometimes, however, during periods of strenuous activity, muscle cells run low on oxygen. The muscles begin to burn and sting. You begin to breathe harder and faster in an effort to supply the needed oxygen. But your body has another method to continue supplying small amounts of energy. When oxygen levels are low, the muscle cells begin to release energy from glucose by fermentation. **Fermentation** is a form of respiration that releases energy from glucose when oxygen is insufficient. Lesser amounts of energy are produced by fermentation. In addition, carbon dioxide and an organic compound called lactic acid are formed. It is lactic acid that causes the muscles to burn and to be sore and stiff. Fermentation takes place in the cytoplasm of cells.

Yeast and some bacteria use fermentation to release energy. Yeast is an organism that breaks down the glucose in bread dough. Carbon dioxide and alcohol are released. The bubbles of carbon dioxide that are released cause the dough to rise. The alcohol is released into the air.

In summary, you can say that producers capture the sun's energy and store it in the form of food. Consumers eat producers. Cells use the glucose made by producers for energy.

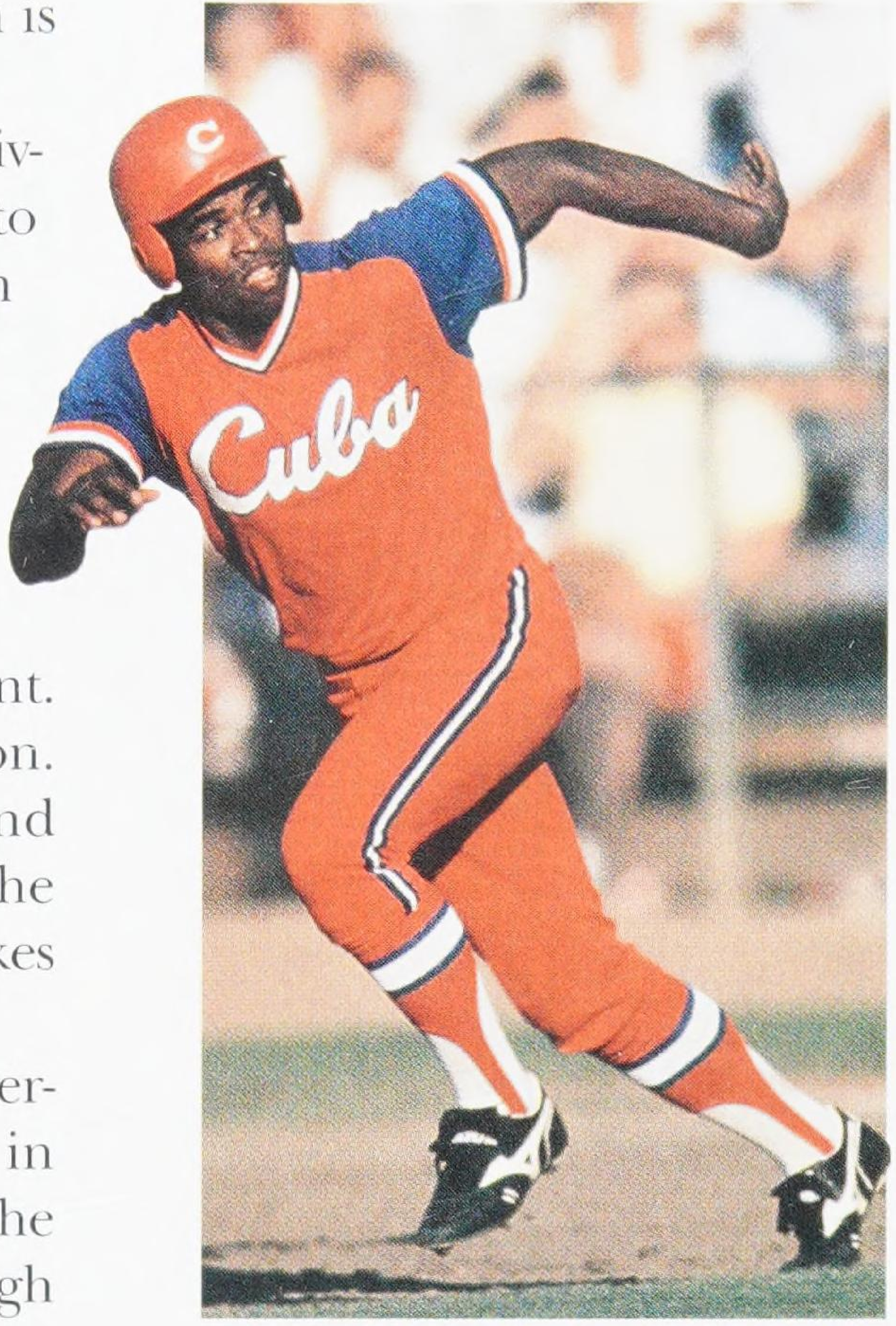


Figure 3-11. During a sprint, oxygen can't be supplied to cells fast enough. Energy is supplied through fermentation and not respiration.

SECTION REVIEW

1. Explain the difference between producers and consumers.
2. How are chloroplasts important to photosynthesis?
3. Under what conditions do cells use fermentation?
4. Explain how the energy used by all living things on Earth can be traced back to sunlight.
5. **Apply:** Plants can use carbon monoxide, CO, instead of CO_2 for photosynthesis. CO is a major component of cigarette smoke. How can indoor plants help to purify the air in a room with cigarette smoke?
6. **Connect to Physics:** Find out how heat produced by respiration and body temperature are related.

Comparing and Contrasting

Skill Builder

Make a table that compares and contrasts respiration and fermentation. If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.

SCIENCE & SOCIETY

3-4 Nonbiodegradable Materials in Your Environment

New Science Words

biodegradable

Objectives

- ▶ Explain the consequences of nonbiodegradable substances in the environment.

Connect to... Chemistry

Bauxite is a claylike raw material that is the major source of aluminum compounds in the world. It takes 95% less energy to recycle aluminum products than it does to remove aluminum from bauxite. From this, what could you infer about the need to mine bauxite if everyone practiced recycling?

Recycling and the Environment

Do you ever drop candy or gum wrappers on the ground? It's likely to be a very long time before these wrappers disappear. Materials such as plastic wrappers and aluminum foil take years to break down in the environment.

Substances that do break down easily in the environment are **biodegradable.** A combination of sunlight, weathering, oxygen, bacteria and fungi, and moisture causes them to decompose, or break down, into the elements they are made of. For example, fruit and leaves are biodegradable. They are plant parts in a cycle that returns nutrients to the soil. Aluminum cans, glass bottles, and plastic bags, which are often seen along roadways, are nonbiodegradable. In fact, all of these take a very long time to decompose. A tin can needs 100 years to break down. An aluminum can requires more than 200 years to break down, and some types of plastics may require 450 years or more!

The situation becomes a problem when you consider the huge amounts of these materials that are dumped into the environment each year. The average United States citizen uses and throws away about 299 kilograms of nonbiodegradable material each year. At this rate, it probably wouldn't take very long for the trash produced by several people to fill up a space the size of a circus tent.

Are these products so bad that we should just stop producing them? That would be difficult. Nearly every day, you are in contact with or using some type of plastic, glass, or aluminum! There is no denying that many lives have been saved thanks to plastics in medical equipment and supplies.

We aren't likely to quit using these products, and the best way to control their use may be to use them over and over again and change them into new products. We call this recycling. Many communities are very interested in finding new uses for nonbiodegradable materials and have begun recycling programs. Glass, plastic, aluminum, paper, and motor oil can all be recycled. Scientists are developing new forms of previously nonbiodegradable products, such as soap, paint, or trash bags, that decompose more easily. By buying such products and making an effort to recycle the others, we can become part of the effort to keep these materials from accumulating and continuing to cause environmental problems.

Remember
ONLY:
Glass
Cans
Plastics
Newspaper
RECYCLING
RECYCLING

SECTION REVIEW

1. Give two ways in which you can help the current problem with nonbiodegradable materials.
2. Discuss how substances decompose naturally, and explain what happens to the materials that are released by decomposition.
3. **Connect to Chemistry:** Find out what becomes of used motor oil.

You Decide!

SCIENCE & SOCIETY

Some states have aluminum can deposit laws. Each empty aluminum can is worth five cents. This is one way to help motivate people to keep the roadsides free from litter. Should all states be required to develop recycling programs?

ACTIVITY 3-2

Photosynthesis and Respiration

Problem: *When do plants carry on photosynthesis?*

Materials

- test tubes, 16 by 150 mm with stoppers (4)
- test-tube rack
- stirring rod
- balance
- sodium bicarbonate
- bromothymol blue solution in dropping bottle
- aged tap water
- pieces of *Elodea* (2)

Procedure

1. Label the test tubes 1 through 4. Fill each tube about three-fourths full with aged tap water.
2. Add 1 g of sodium bicarbonate to each test tube. Sodium bicarbonate releases carbon dioxide when mixed with water.
3. Add 5 drops of bromothymol blue solution to each test tube. Bromothymol blue turns green to yellow in the presence of an acid.
4. Cut two 10-cm pieces of *Elodea*. Place one piece of *Elodea* in test tube 1 and one piece in test tube 3. Stopper the test tubes. Record the color of the solution in each test tube.
5. Place test tubes 1 and 2 in bright light and test tubes 3 and 4 in the dark for 30 minutes.
6. Observe the test tubes and record the colors.

Analyze

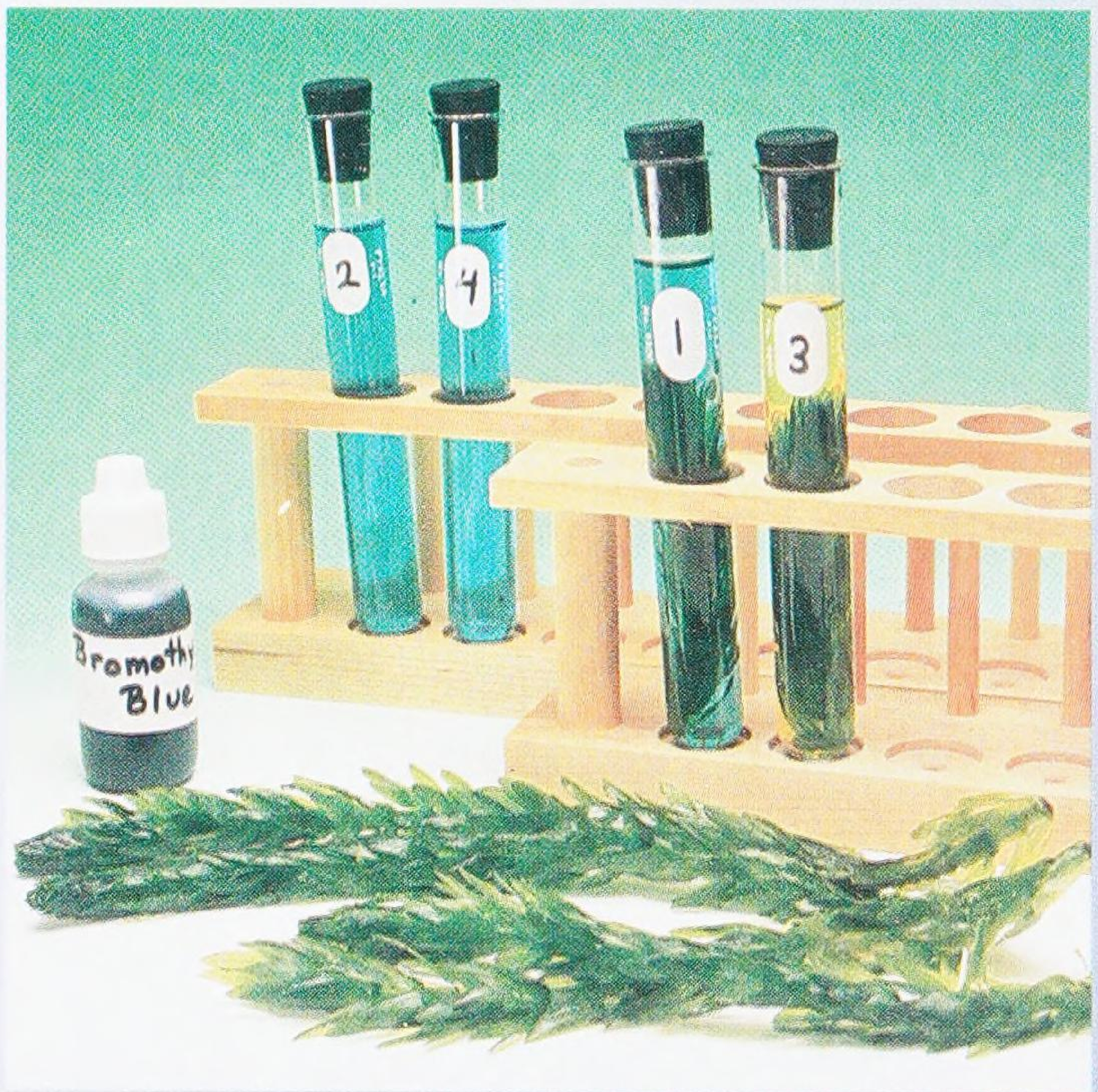
1. What is indicated by the color of the water in all four tubes at the start of the activity?
2. What color were the liquids in tubes 1 and 3 after 30 minutes?
3. What color were the liquids in tubes 2 and 4 after 30 minutes?

Data and Observations

Test tube	Color at start	Color after 30 minutes
1		
2		
3		
4		

Conclude and Apply

4. Describe the purpose of tubes 2 and 4.
5. Explain the color of the liquid in tube 1 after 30 minutes.
6. Explain the color of the liquid in tube 3 after 30 minutes.
7. From your observations, *infer* when a green plant carries out photosynthesis.



CHAPTER REVIEW

SUMMARY

3-1: Chemistry of Living Things

1. Everything is made of matter, which is composed of atoms arranged in elements, molecules and compounds.

2. Both inorganic and organic molecules are important to living things.

3. Carbohydrates, lipids, proteins, and nucleic acids are organic compounds. Inorganic compounds do not contain carbon.

3-2: Cell Transport

1. The cell membrane controls what molecules can pass through it.

2. Molecules move by diffusion from areas of greater numbers to areas of lesser numbers. In osmosis, water diffuses through a membrane.

3. The cell expends energy to move molecules by active transport, but not by passive transport.

3-3: Energy in Cells

1. Producers make energy in the form of food, which consumers eat.

2. Green plants use light energy to make chemical energy in the form of glucose during photosynthesis. In respiration, glucose is broken down and energy is released.

3. Some yeasts, bacteria, and oxygen-deprived cells carry out fermentation to release small amounts of energy from glucose without using oxygen.

3-4: Science and Society: Nonbiodegradable Materials in Your Environment

1. Nonbiodegradable substances do not break down easily in the environment and accumulate as wastes.

KEY SCIENCE WORDS

a. **active transport**
b. **biodegradable**
c. **carbohydrates**
d. **cellular respiration**
e. **consumers**
f. **diffision**
g. **endocytosis**
h. **enzymes**
i. **equilibrium**
j. **exocytosis**
k. **fermentation**
l. **lipids**
m. **metabolism**
n. **nucleic acids**
o. **osmosis**
p. **passive transport**
q. **photosynthesis**
r. **producers**
s. **proteins**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. organisms that make their own food
2. the movement of water molecules through a membrane
3. movement of molecules that requires energy
4. substance that is broken down in the environment by bacteria or fungi
5. capable of releasing more energy than carbohydrates
6. sugar, starch, and cellulose
7. made up of amino acids
8. use of light energy to make food
9. release of a substance from a small sac at the membrane
10. the breakdown of glucose without the presence of oxygen

CHAPTER

REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. Energy is used to move molecules by _____.
a. diffusion **c.** osmosis
b. active transport **d.** passive transport

2. Bacteria are taken into cells by ______.
a. osmosis **c.** exocytosis
b. endocytosis **d.** diffusion

3. An example of an organic compound is _____.
a. $C_6H_{12}O_6$ **c.** H_2O
b. NO_2 **d.** O_2

4. _______ are examples of carbohydrates.
a. Enzymes **c.** Waxes
b. Sugars **d.** Proteins

5. Organic compounds in the chromosomes are _______.
a. carbohydrates **c.** lipids
b. water molecules **d.** nucleic acids

6. The organic molecule that releases the greatest amount of energy is _______.
a. carbohydrate **c.** lipid
b. water **d.** nucleic acid

7. Salt is a(n) _______ molecule.
a. organic **c.** carbohydrate
b. lipid **d.** inorganic

8. _______ occurs when molecules are evenly distributed.
a. Equilibrium **c.** Fermentation
b. Metabolism **d.** Cellular respiration

9. _______ are organisms that can't make their own food.
a. Biodegradables **c.** Consumers
b. Producers **d.** Enzymes

10. Chlorophyll is needed for _______.
a. fermentation **c.** diffusion
b. cellular respiration **d.** photosynthesis

USING LAB SKILLS

11. In Activity 3-1 on page 62, you studied osmosis in an egg. Place 10 to 12 raisins in a glass of water and allow them to stand overnight. Explain your results.

12. The Mini-Lab on page 57 asked you to find out how enzymes work. Label two containers A and B. Make 1 cup of prepared instant pudding and divide it between the two containers. Add 1 teaspoon of fresh pineapple juice to container A and stir. Add 1 teaspoon of canned pineapple juice to container B and use a clean spoon to sir. What can you infer about differences between canned and fresh pineapple juice? What can you infer about your results in terms of enzyme activity?

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Compare and contrast diffusion and osmosis.

14. Why might there be many more mitochondria in muscle cells than in other types of cells?

15. Explain how some substances, but not others, can pass through the cell membrane.

16. Describe how a cell reaches equilibrium with its environment if there are ten water molecules inside and 24 molecules outside.

17. During the night, what happens to the starch the plant made and stored in its leaves?

APPLY

18. If you could place a single red blood cell in a glass of distilled water, what do you think you would see happen to the cell? Explain.
19. In snowy states, salt is used to melt ice on the roads. Explain what happens to many roadside plants as a result.
20. Explain why sugar dissolves faster in hot tea than in iced tea.
21. Explain what would happen to the consumers in a lake if all the producers died.
22. Meat tenderizers contain enzymes. How do these enzymes affect protein in meat?

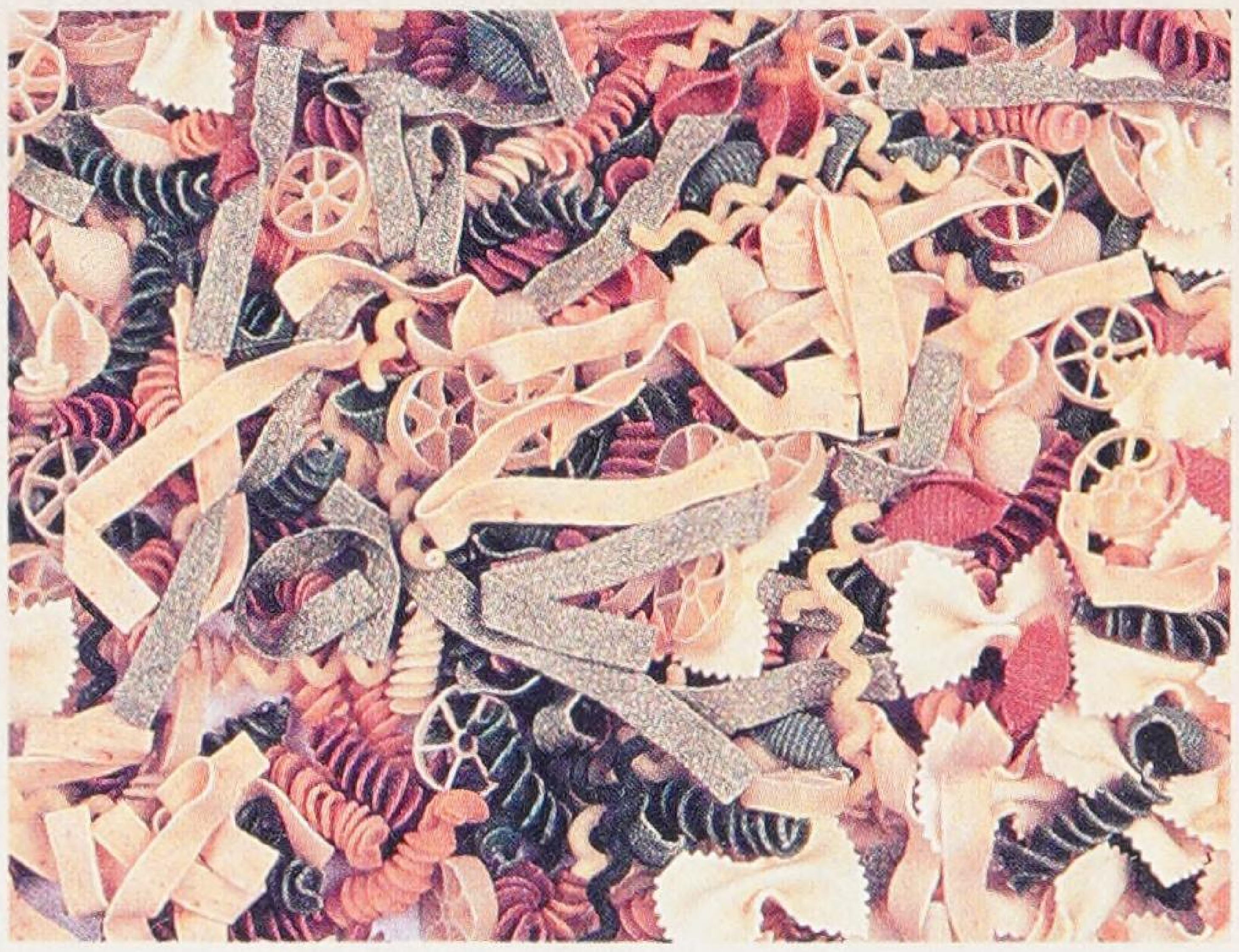
MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Interpreting Data:** In an experiment that tests the rate of photosynthesis in water plants, the water plants were placed at different distances from a light source. Bubbles of gas coming from the plants were counted to measure the rate. What can you say about how the rate is affected by the light?

Beaker Number	Distance from Light	Bubbles per minute
1	10 cm	45
2	30 cm	30
3	50 cm	19
4	70 cm	6
5	100 cm	1

2. **Making and Using Graphs:** Use the data from Question 1 to graph the relationship between photosynthesis rate and distance from light.
3. **Classifying:** Classify these common foods into a category of carbohydrates, lipids, or proteins: butter, bread, candy bar, cereals, cheese, cornstarch, fish, margarine, meats, pasta, peanut butter, shortening, sugar, vegetable oil.



4. **Concept Mapping:** Sequence the parts of matter from smallest to largest: element, atom, compound in an events chain concept map.
5. **Hypothesizing:** Make a hypothesis about what will happen to wilted celery when placed into a glass of plain water.

PROJECTS

1. Design an experiment to show that respiration takes place in growing lima bean seeds.
2. Make a list of elements found in ten substances in your home. Use the labels to determine the elements each product contains.

CHAPTER

4

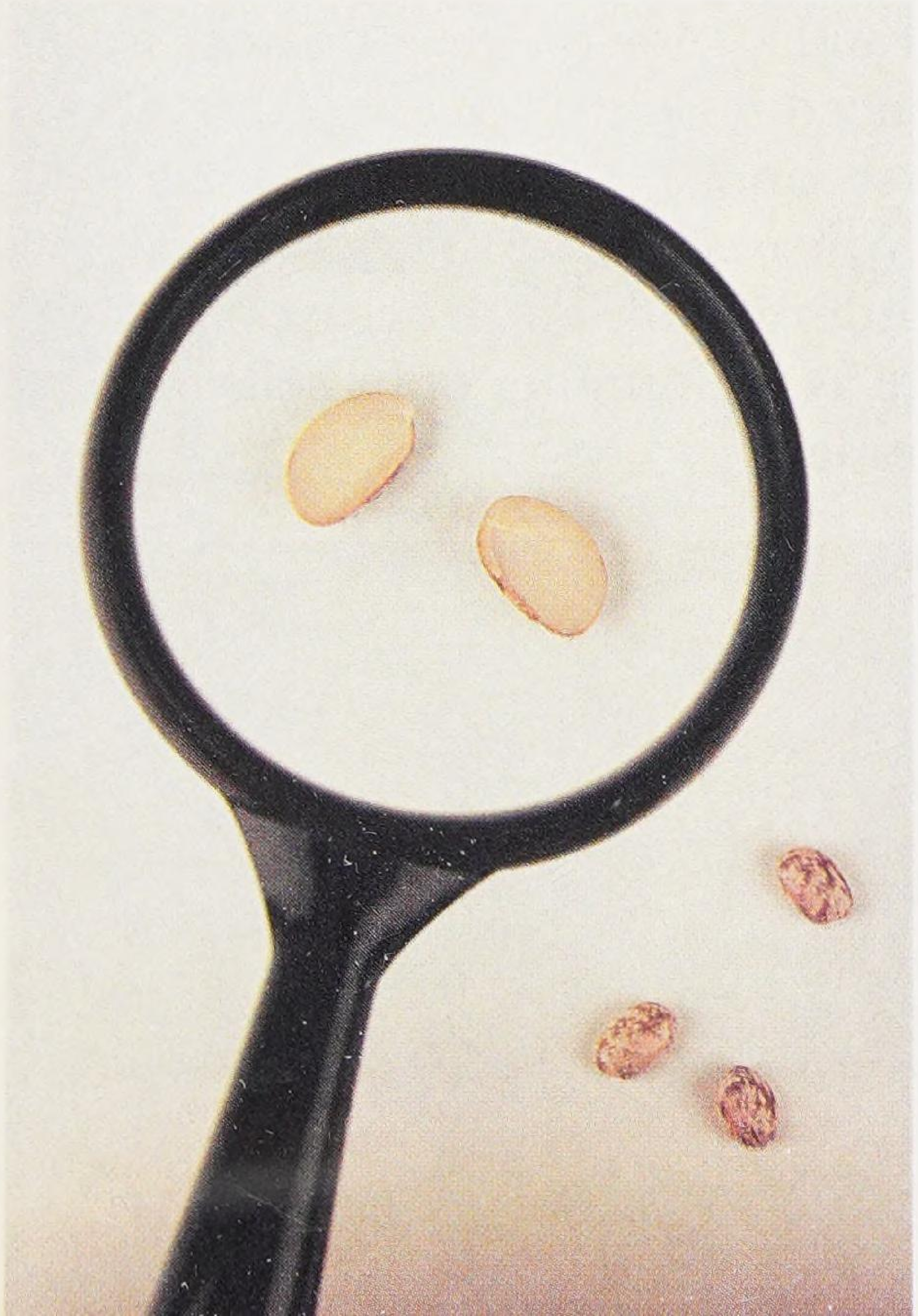
Cell Reproduction

Do you know that your life hangs by a thread? Miles of thread-like DNA and protein condense to make up chromosomes in your cells, similar to the one to the left. When cells divide and organisms grow, chromosomes are the carriers of the information that shapes each new cell.

FIND OUT!

Do this activity to see what changes take place in a plant as it develops.

Carefully split open a pinto bean seed that has soaked in water overnight. Look at it with a hand lens. What do you think you find inside the top part of the seed? Place four other bean seeds in a moist paper towel in a plastic bag. *Observe* the seeds for a few days. What happened inside the seed? *Infer* how this happened.



Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 4-1 Cell Growth and Division
- What Happens When Cells Divide?
- The Cell Cycle
- Mitosis
- Types of Reproduction

Section 4-2 Sexual Reproduction and Meiosis
- Sexual Reproduction
- The Importance of Sex Cells
- Meiosis—Sex Cell Formation

Section 4-3 DNA
- What Is DNA?
- How DNA Copies Itself
- DNA and Genes
- Mutations

Section 4-4 Science and Society Inventing Organisms
- Transgenic Organisms
- Patenting Life

Previewing Science Skills

- In the **Skill Builders,** you will outline, make a table, and make a concept map.
- In the **Activities,** you will observe, compare, infer, experiment, and make a model.
- In the **MINI-Labs,** you will make a model and sequence events.

What's next?

In this chapter, you'll learn how cells divide and how organisms reproduce. You'll also learn about DNA—how it reproduces and controls proteins produced in the cells of an organism.

4-1 Cell Growth and Division

New Science Words

mitosis
chromosomes
asexual reproduction
sexual reproduction

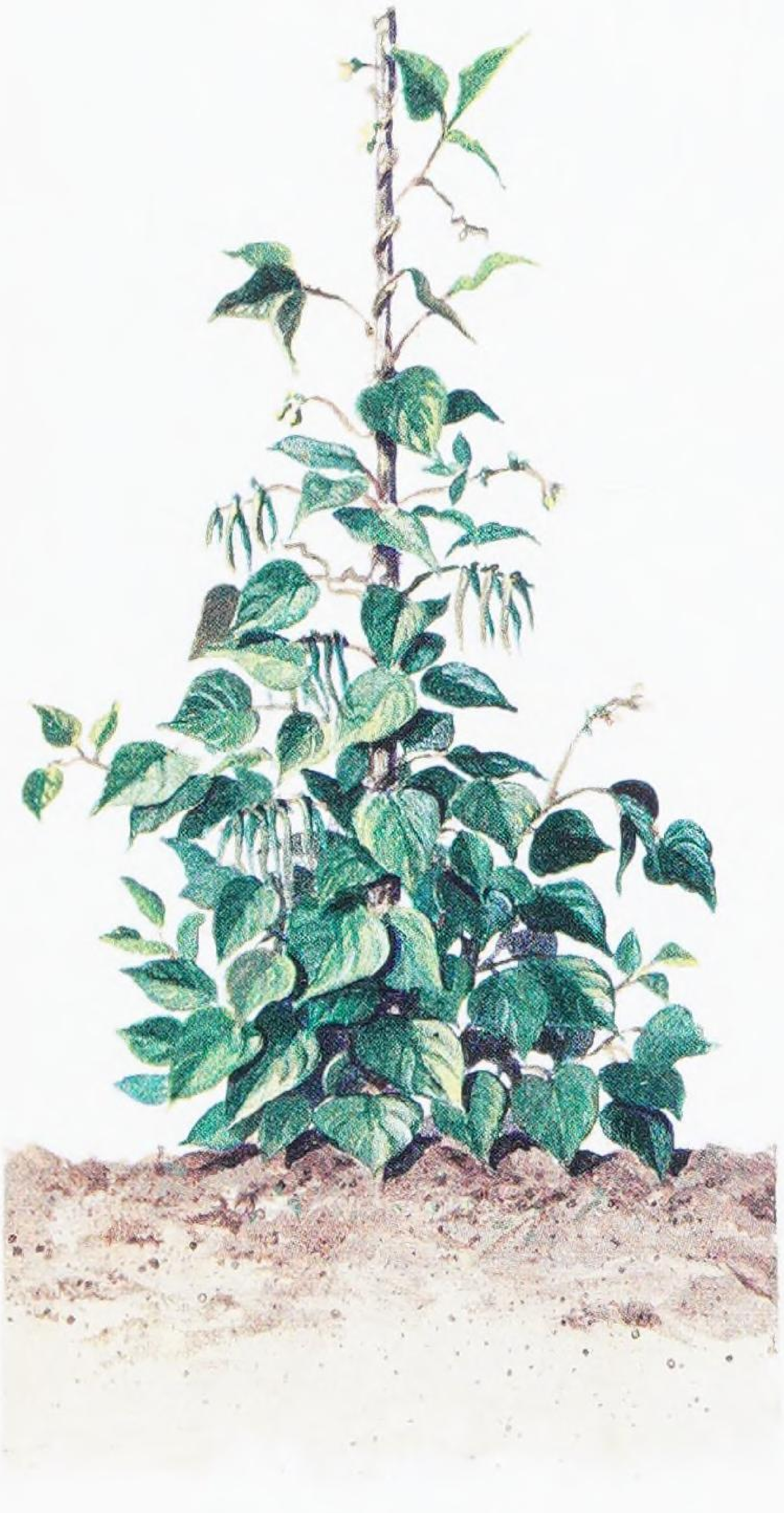
Objectives

- Describe mitosis and explain its importance.
- Explain differences between mitosis in plant and animal cells.
- Distinguish between asexual and sexual reproduction and give two examples of asexual reproduction.

What Happens When Cells Divide?

It's very likely that each time you go to the doctor, a nurse measures your height and mass. Over the years, similar data collected from thousands of people have given the medical profession an idea of how people grow. Much of the growth happens because the number of cells in your body increases over the years. Other growth occurs because some cells become larger in size through metabolism.

The fact is that you are constantly changing. You aren't the same now as you were a year ago or even a few hours ago. At this very moment, as you read this page, groups of cells throughout your body are growing, dividing, and dying. Worn-out cells on the palms of your hands are being replaced. Cuts and bruises are healing. Red blood cells are being produced in your bones at a rate of two to three billion per second to replace those that wear out. Muscles that you exercise are getting larger. Other organisms undergo similar processes. A plant climbs a garden stake as the number of its cells increases. How does this happen?



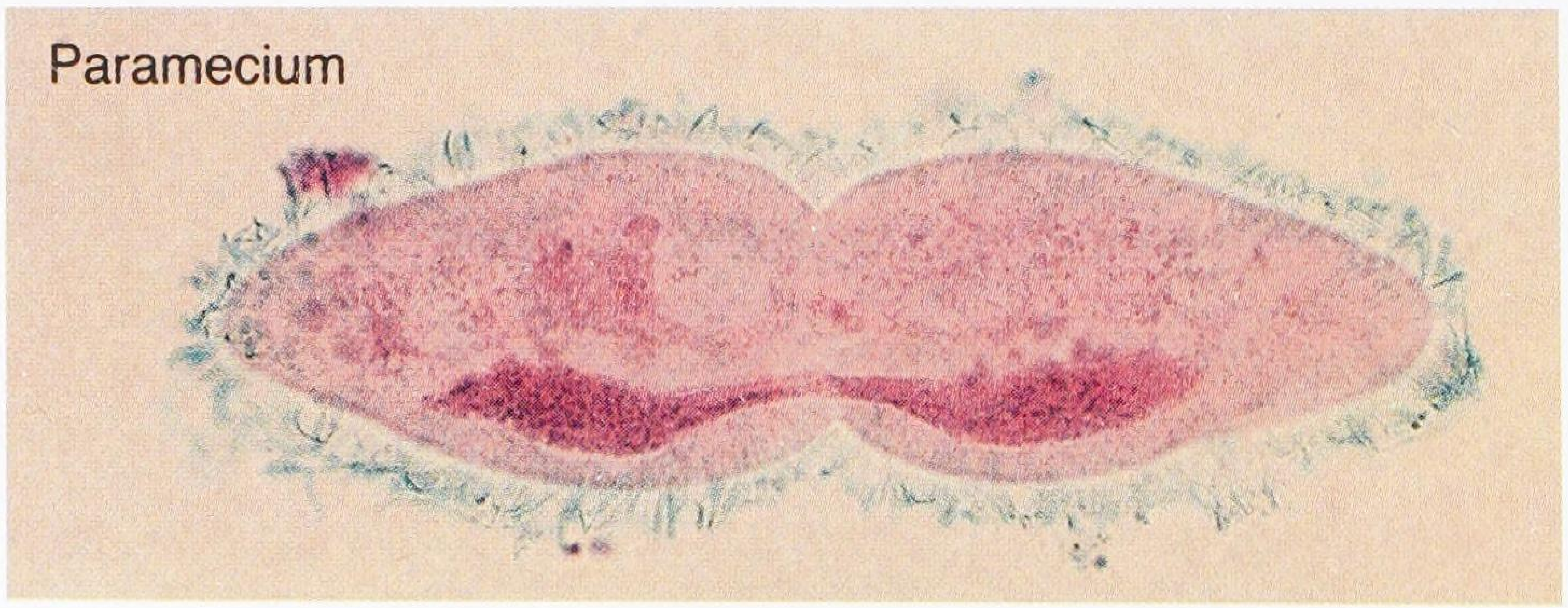


Figure 4-1. Many-celled organisms, such as the pole-bean plant above, grow by increasing numbers of cells. A one-celled organism reaches a certain size and then divides.

The Cell Cycle

Organisms go through stages, or a life cycle, while they are alive. A simple life cycle is birth, growth and development, and death. Right now, you are in a stage in your life cycle called adolescence, a period of active growth and development. Cells also go through cycles. Most of the life of any cell is spent in a period of growth and development called *interphase.* Cells in your body that no longer divide, such as nerve and muscle cells, are always in interphase. Cells that actively divide, such as your skin cells, have a more complex cell cycle. The cell cycle, as shown in Figure 4-2, is a series of events that takes place in a cell from one division to the next.

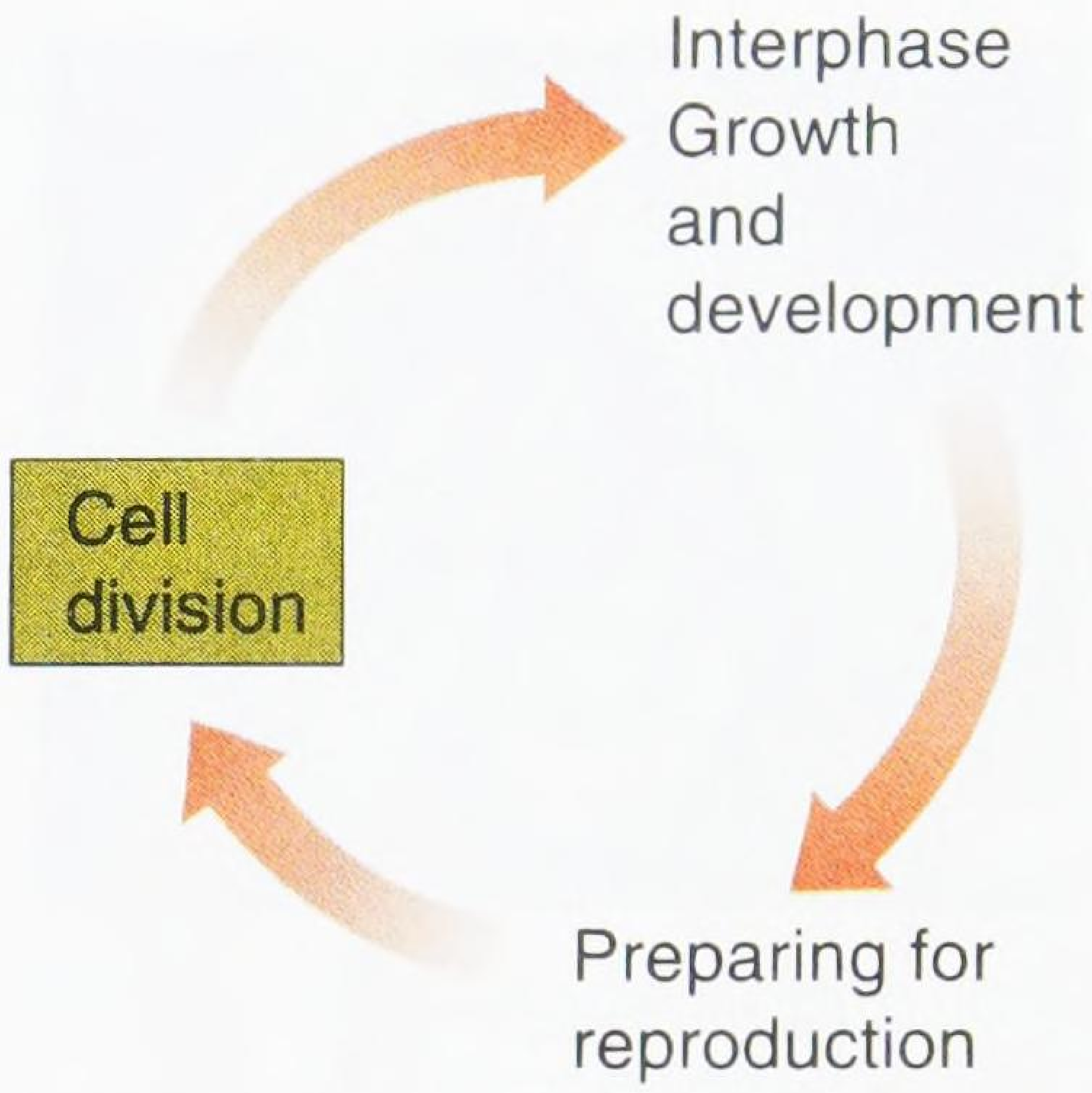


Figure 4-2. A Cell Cycle

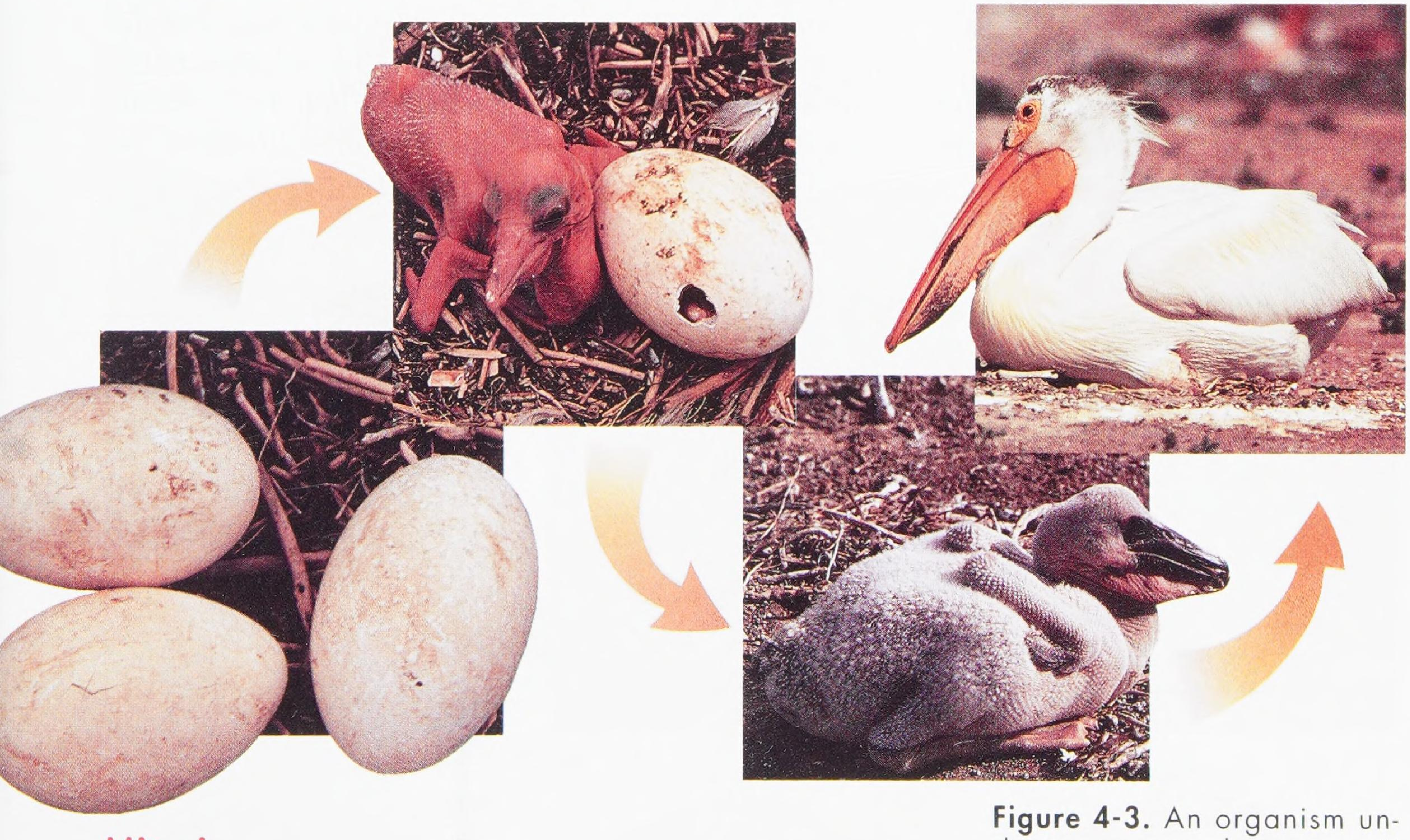


Figure 4-3. An organism undergoes many changes as it develops. These photographs show some of the stages in the development of a pelican.

Mitosis

Cells divide in two steps. First the nucleus of the cell divides, and then the cytoplasm divides. **Mitosis** is the process in which a cell nucleus divides into two new nuclei, each of which contain the same number of chromosomes as the parent cell. The parent cell is the cell that undergoes division. Mitosis is described as a series of steps. These steps have been named prophase, metaphase, anaphase, and telophase.

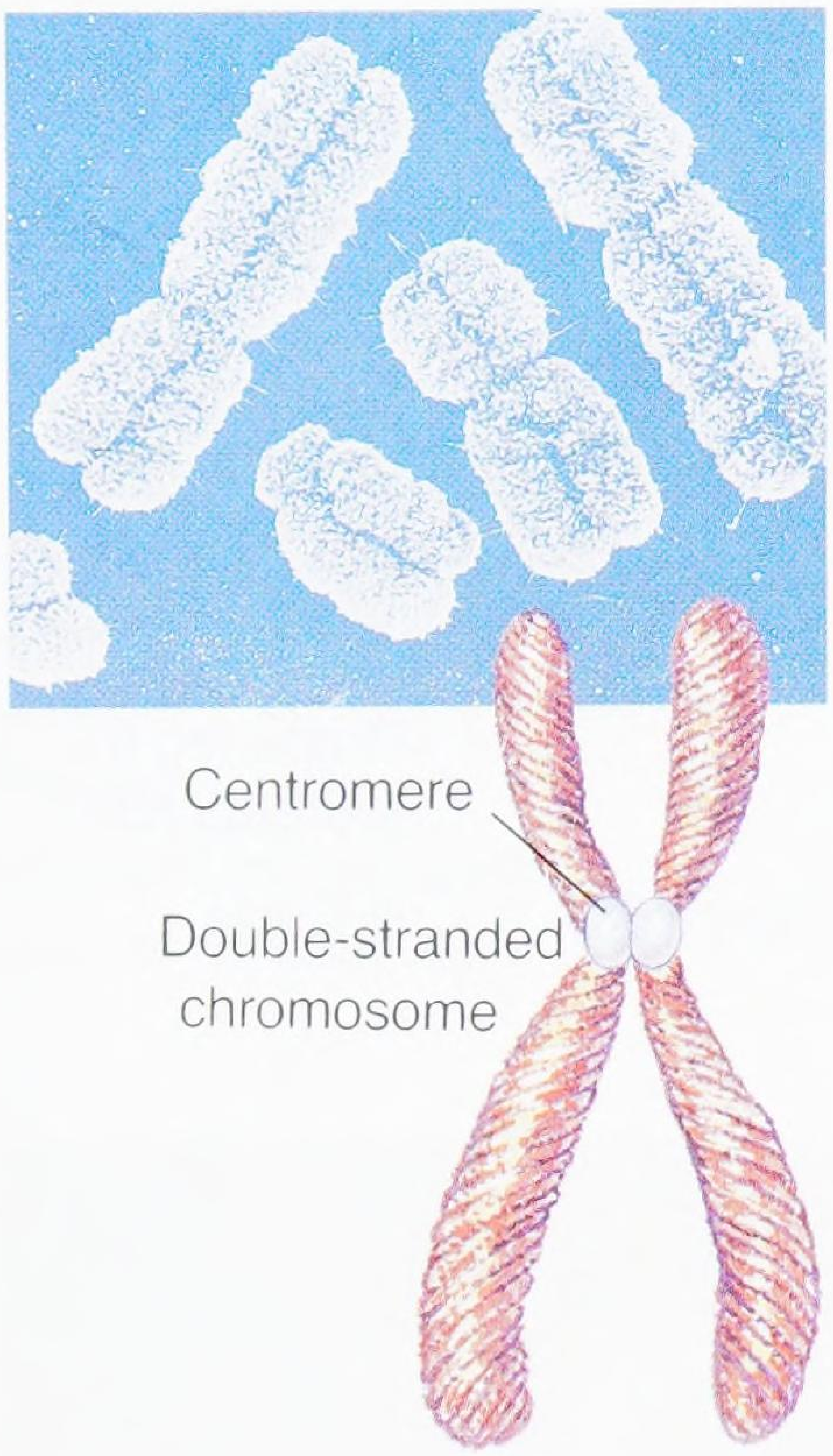
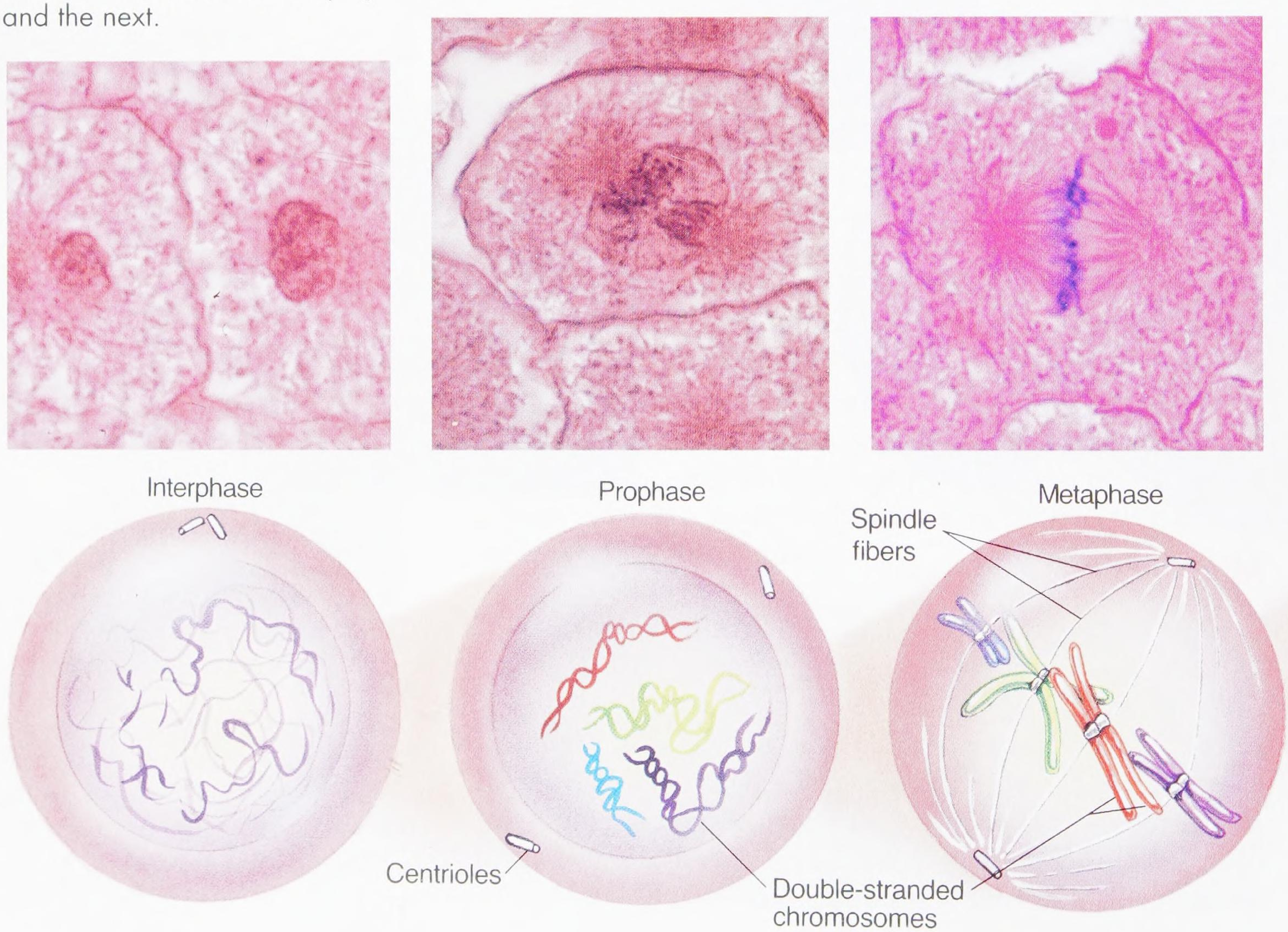

Centromere
Double-stranded chromosome

Figure 4-4. The steps of mitosis are shown in order on this page and the next.

Steps of Mitosis

When a cell divides, the chromosomes in the nucleus play the most important part. **Chromosomes** are structures in the nucleus that contain DNA. During *interphase,* you can't see chromosomes but they are actively duplicating themselves. Then they condense and become visible. When the chromosomes appear, they are thick and doubled-stranded as in the illustrations on the left. Each double-stranded chromosome is held together at a region called a centromere. Once chromosomes are double-stranded, the cell is ready to begin the process of division. Follow the steps of mitosis in the illustrations in Figure 4-4 on these pages.

During *prophase,* chromosomes become fully visible. The nucleolus and the nuclear membrane fade and disappear. In animal cells, two small structures called centrioles move to opposite ends of the cell. Between the centrioles, threadlike spindle fibers begin to stretch across the cell, making a football-shaped network of fibers. Plant cells don't have centrioles.


Interphase
Prophase
Metaphase
Spindle fibers
Centrioles
Double-stranded chromosomes

In the second step, *metaphase,* the double-stranded chromosomes line up around the center of the cell. Each centromere becomes attached to a spindle fiber. As the process enters *anaphase,* each centromere divides. The two strands of each chromosome separate. Then, the separate strands begin to move away from each other toward opposite ends of the cell.

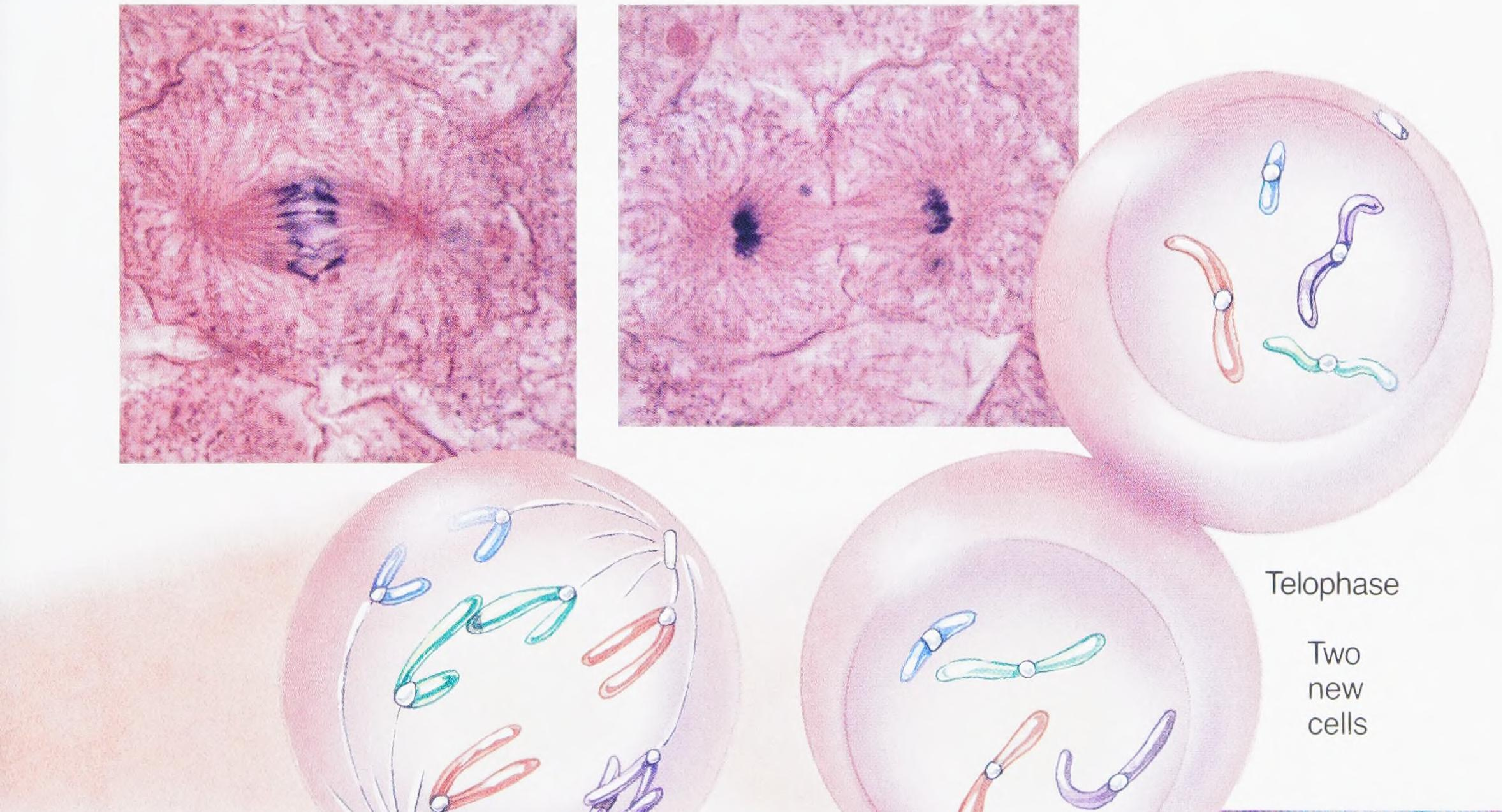
In the final step of mitosis, *telophase,* centrioles and spindle fibers start to disappear. The chromosomes stretch out and become harder to see. A nuclear membrane forms around each mass of chromosomes, and a new nucleolus appears in each new nucleus.

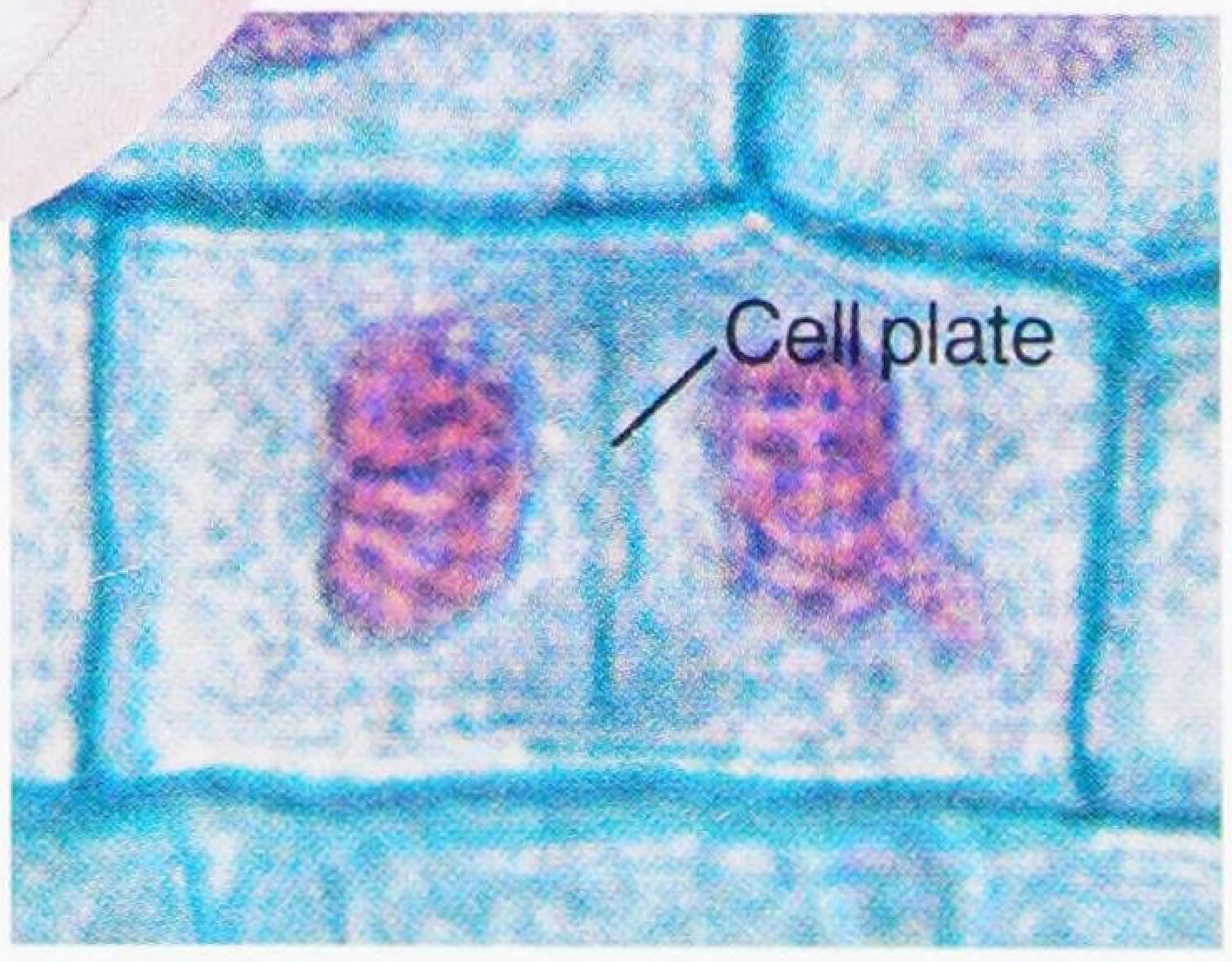
Science and MATH

If a single cell undergoes mitosis every five minutes, how many cells will result from this single cell after one hour? *Calculate* the answer and record it **in your Journal**.

During what phase does a new nuclear membrane form?

In most organisms, once the nucleus has divided, the cytoplasm also separates and two whole new cells are formed. In animal cells, the cytoplasm pinches in to form the new cells. The new cells then begin a period of growth. They will take in water and other nutrients that they need to carry out cell processes.





Plant cells have rigid cell walls and do not pinch apart as animal cells do. Instead, a structure called a cell plate forms between the two new nuclei. New cell walls form along the cell plate. Plant cells do not have centrioles, but they do have spindle fibers during mitosis.

MINI-Lab

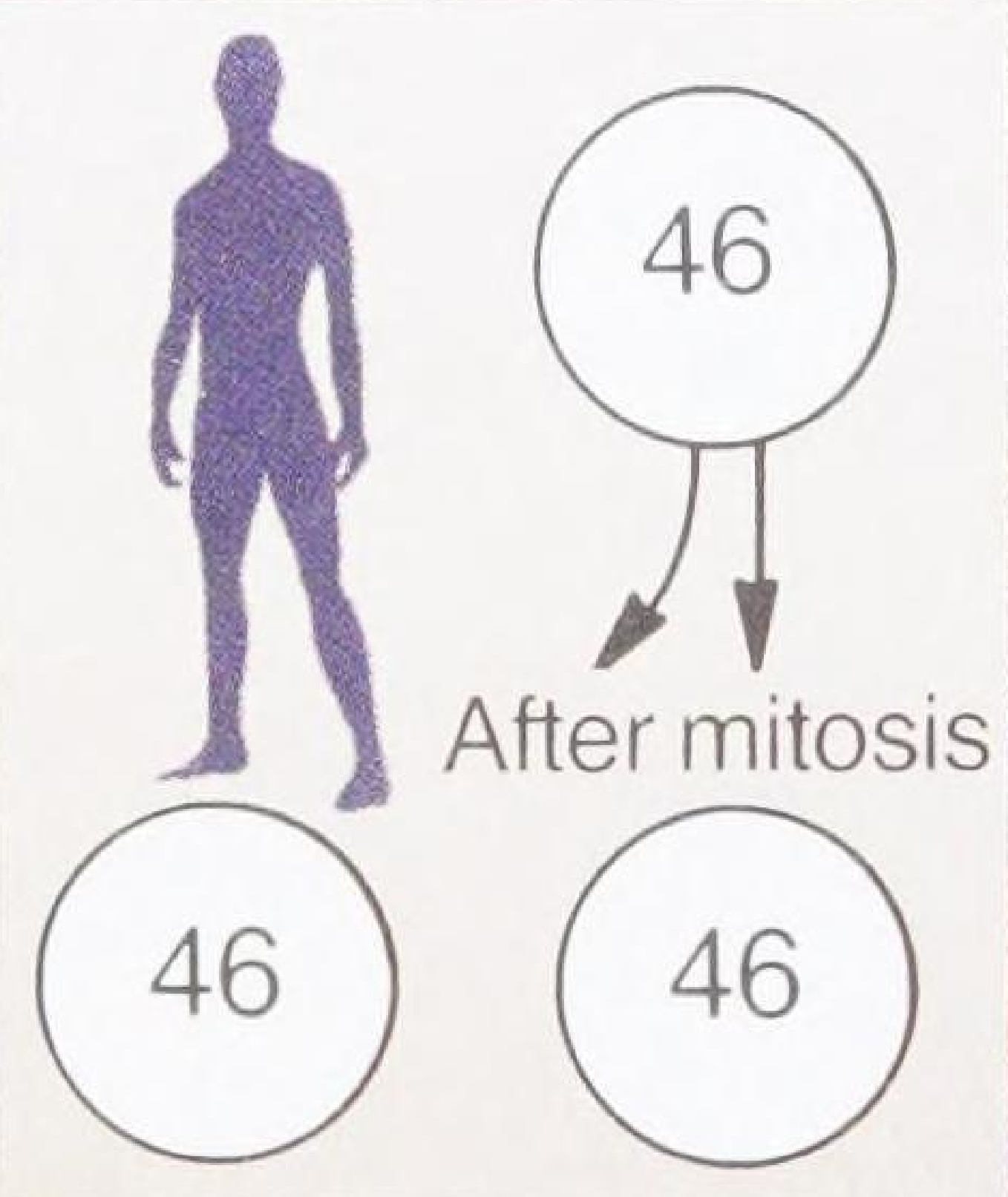
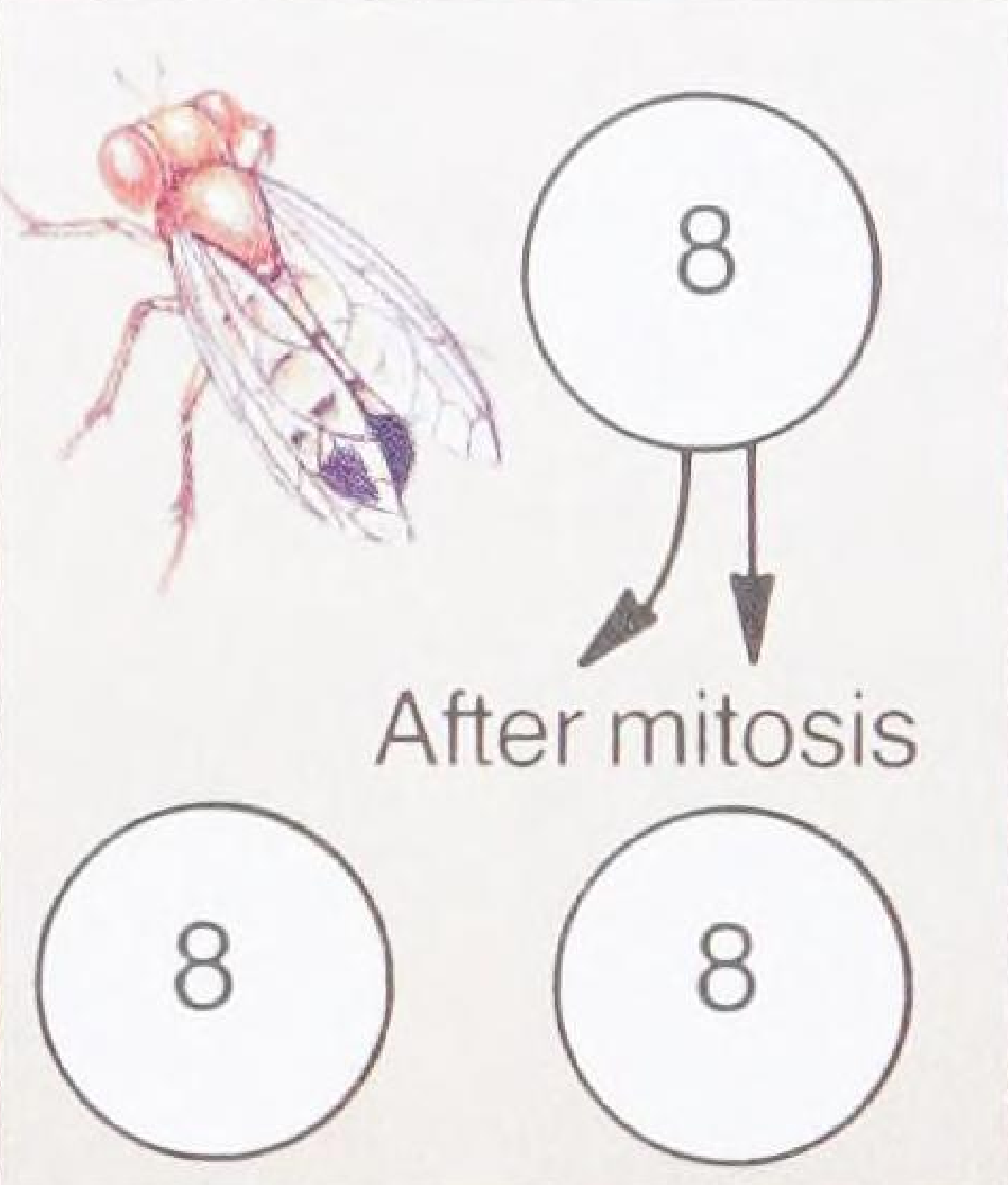
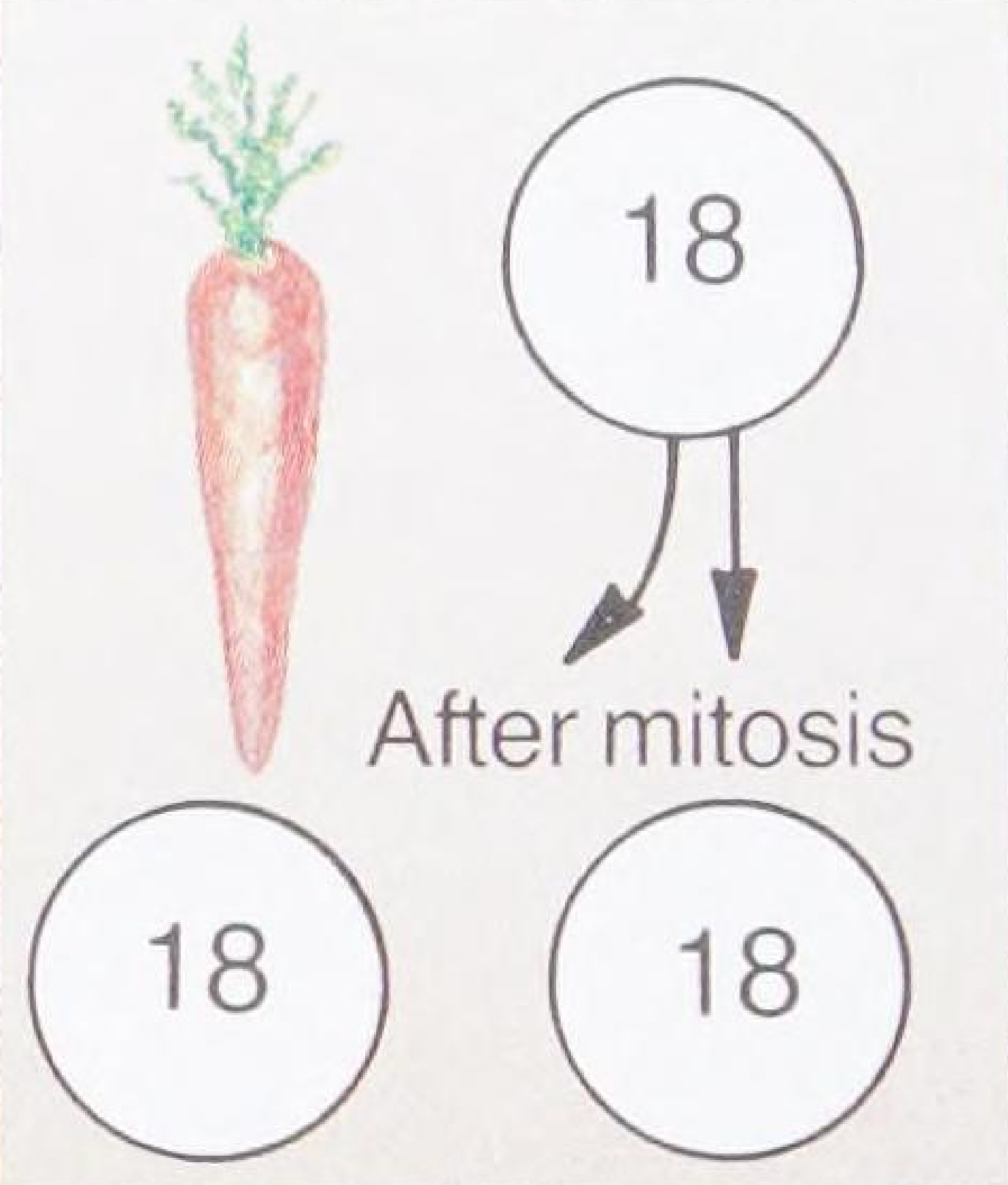
How does one cell become two?

Work in Paired Partners to *construct models* showing the different stages in mitosis. Use a cell with four chromosomes. Show each phase on a separate poster. Use yarn for chromosomes, sewing thread for spindle fibers, and nickel-sized paper dots for centrioles. Put the posters in correct sequence.

There are two important things to remember about mitosis. The first is that mitosis is the division of a nucleus. The second is that mitosis produces two new nuclei that have the same number of chromosomes as the original nucleus. Cells in your skin, like most of the cells in your body, each have 46 chromosomes. Each new skin cell produced by mitosis will also have 46 chromosomes. Cells in fruit flies have eight chromosomes. New fruit fly cells produced by mitosis will each have only eight chromosomes. Table 4-1 shows an additional example.

Table 4-1

CHROMOSOME NUMBERS

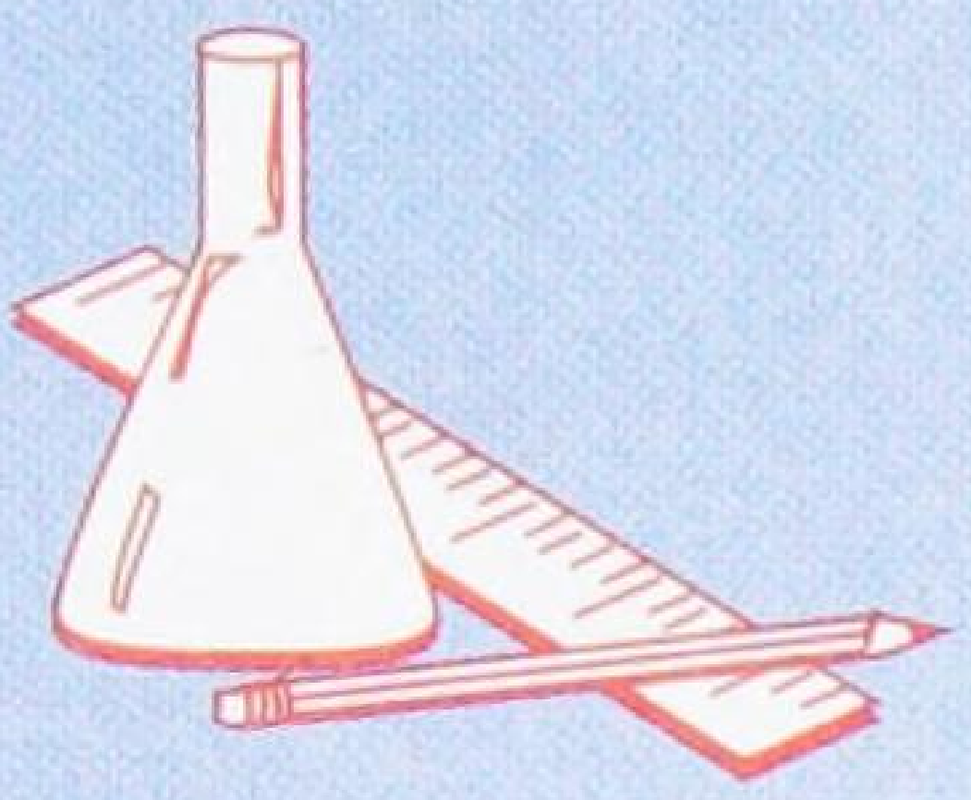
Humans	Fruit Flies	Carrots
 46 After mitosis 46 46	 8 After mitosis 8 8	 18 After mitosis 18 18

PROBLEM SOLVING

Cell Biology and Cancer Research

Jewel Plummer Cobb first became fascinated with cells when she saw them through a microscope in high school. She has spent her life researching cells and is now one of the leading cancer researchers in the United States. Cancer is the result of uncontrolled cell division. Dr. Cobb's cancer research has been in two major areas. First, she wanted to find anti-cancer drugs that would not damage normal cells. Second, Dr. Cobb solved a major problem of cancer research by developing methods for growing human cancer cells in the laboratory.

Think Critically: What advantages are there in using cells grown in a lab rather than cells in a living person for research?



ACTIVITY 4-1

Mitosis in Plant and Animal Cells

Problem: *How is mitosis in a plant cell different from mitosis in an animal cell?*

Materials

- prepared slide of an onion root tip
- prepared slide of a whitefish embryo
- microscope

Procedure

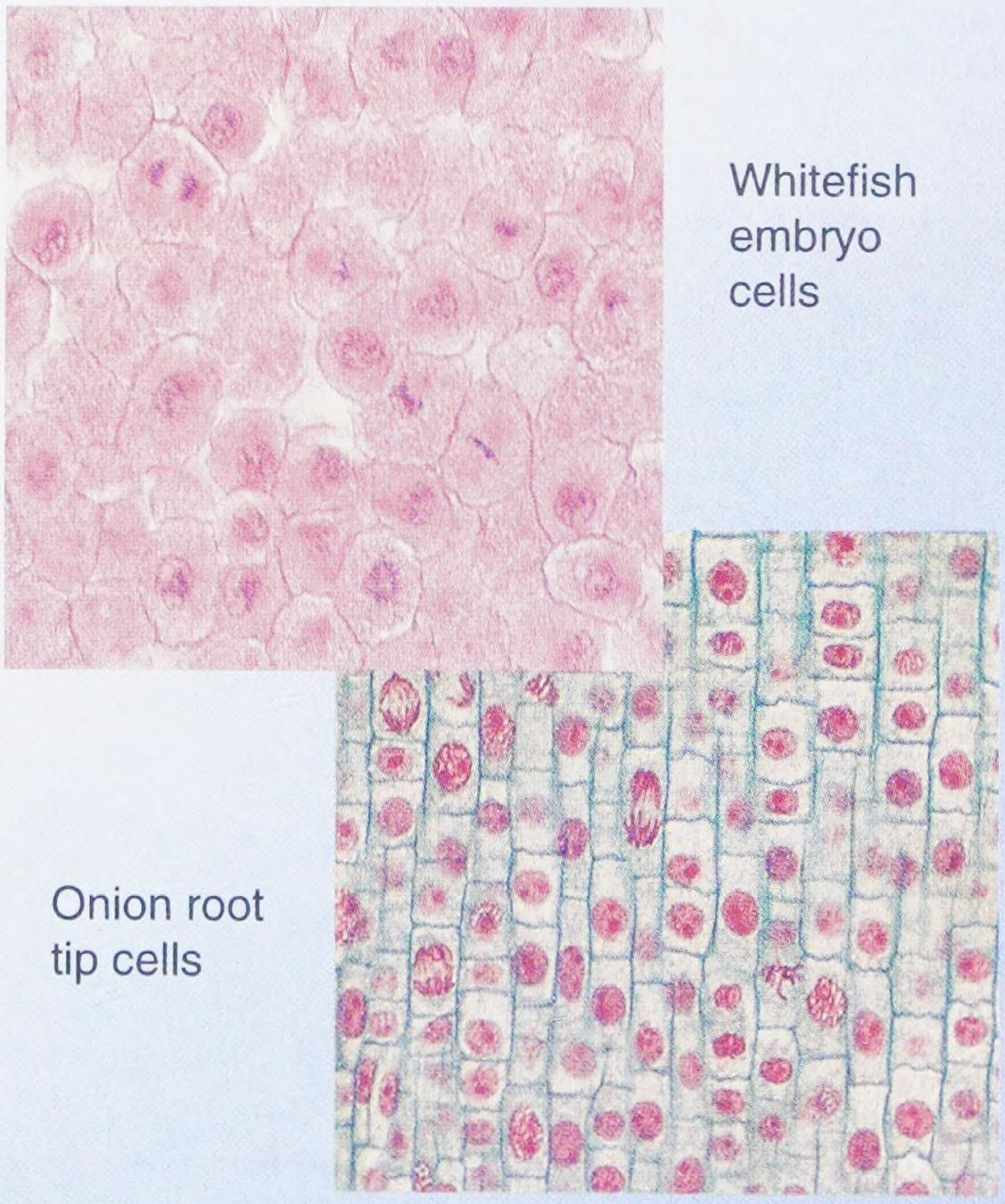
1. Obtain prepared slides of onion root tip and whitefish embryo.
2. Set your microscope on low power and examine the onion root tip. Move the slide until you can see the area just behind the root tip. Turn the nosepiece to high power.
3. Use Figure 4-4 on pages 76-77 to help you find a cell in interphase. Draw and label the parts of the cell you observe.
4. Repeat Step 3 for prophase, metaphase, anaphase, and telophase.
5. Turn the microscope back to low power. Remove the onion root tip slide.
6. Place the whitefish embryo slide on the microscope stage under low power. Focus and find a region of dividing cells. Turn the microscope to high power.
7. Use Figure 4-4 to help you find a cell in interphase. In a data table, draw and label the parts of the cell you observe.
8. Repeat Step 7 for prophase, metaphase, anaphase, and telophase.
9. Return the nosepiece to low power. Remove the whitefish embryo slide from the microscope stage.

Analyze

1. How are the cells in the region behind the onion root tip different from those in the root tip?
2. What is the shape of the cells in the onion root tip?
3. In which stage do the chromosomes move to the center of the cell?
4. When do the chromosomes move to opposite ends of the cell?
5. What is the shape of the cells in the whitefish embryo?
6. When do the spindle fibers appear in both the onion root tip and the whitefish embryo?

Conclude and Apply

7. How do the whitefish embryo cells and the onion root tip cells *compare* in size?
8. How do the chromosomes of the whitefish embryo *compare* with those of an onion root tip?
9. What can you *conclude* about mitosis in the onion and in the whitefish embryo?



Types of Reproduction

Your body forms two types of cells—body cells and sex cells. Skin, liver, bones, kidneys, lungs, and muscles are made up of different types of body cells. By far, your body has many more body cells than sex cells. The only sex cells that you have are the eggs or sperm in your reproductive organs.

Reproduction is the process by which an organism produces others of the same kind. Among living organisms, there are two types of reproduction—asexual reproduction and sexual reproduction. In **asexual reproduction,** new organisms are produced from one parent. You've just seen examples of this in the process of mitosis. Offspring produced by asexual reproduction have DNA that is identical to the DNA of the parent organism.

Several types of asexual reproduction are important in plants and animals. If you've ever grown a sweet potato in a jar of water, you've seen asexual reproduction take place. All the stems and leaves that grow out from the sweet potato have been produced by mitosis. New strawberry plants can be produced asexually from runners. Bacterial cells reproduce asexually by a process called fission. Fission is division of an organism into two equal parts.

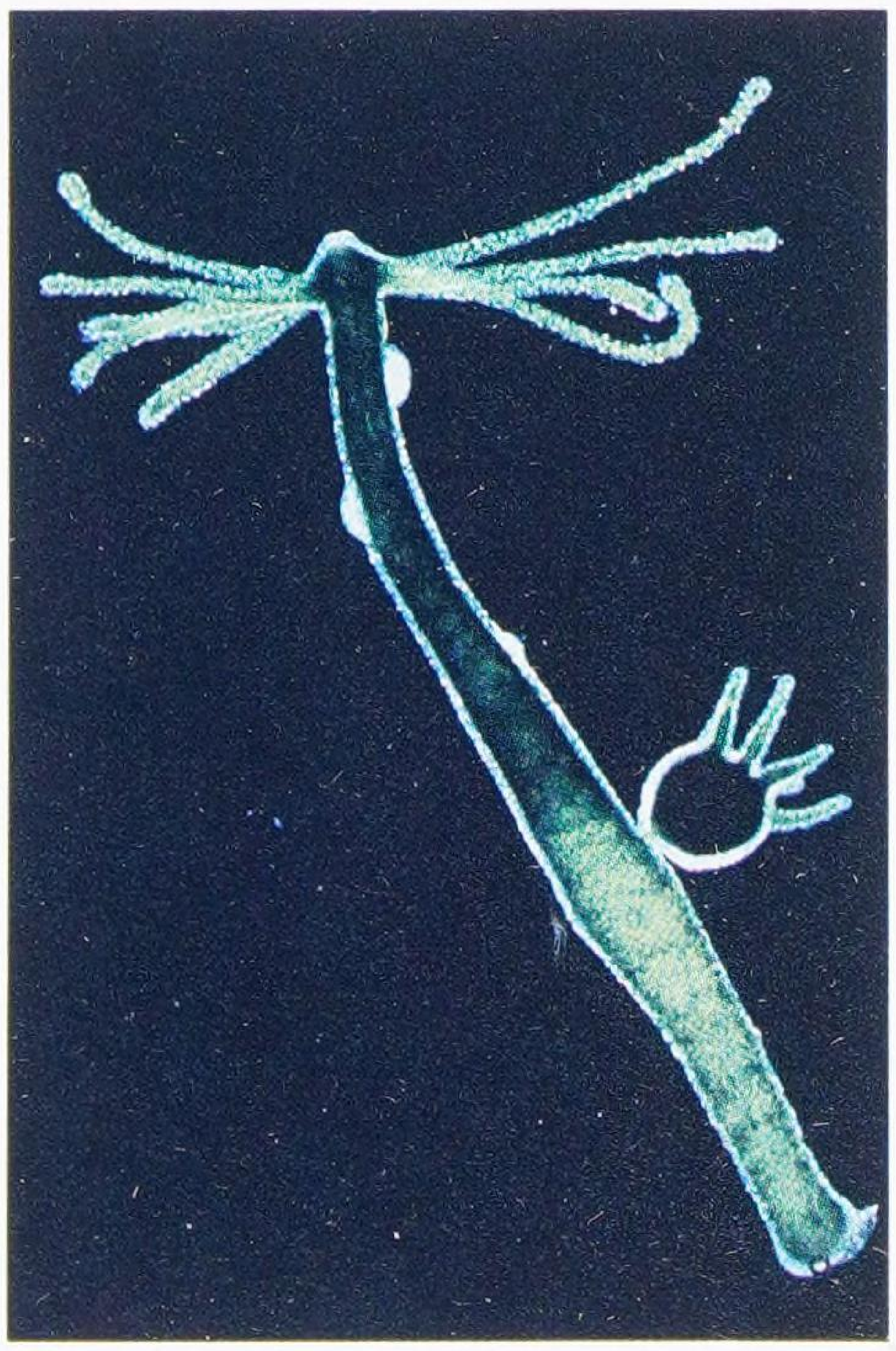
Budding is also a type of asexual reproduction in which a new organism grows from the body of the parent organism. Hydra can reproduce this way. When the bud on the adult becomes large enough, it breaks away to live on its own.

A few organisms can repair damaged or lost body parts by regeneration. During regeneration, new organisms may grow from a piece of the parent organism. Sponges, planaria, and sea stars undergo regeneration. If the cells of a live sponge are separated, they collect together and

Connect to... Earth Science

Many nonliving things, such as icicles, crystals, and sand dunes, appear to grow. Distinguish between the processes involved in the growth of living things and the "growth" of nonliving things.

How do asexual and sexual reproduction differ?



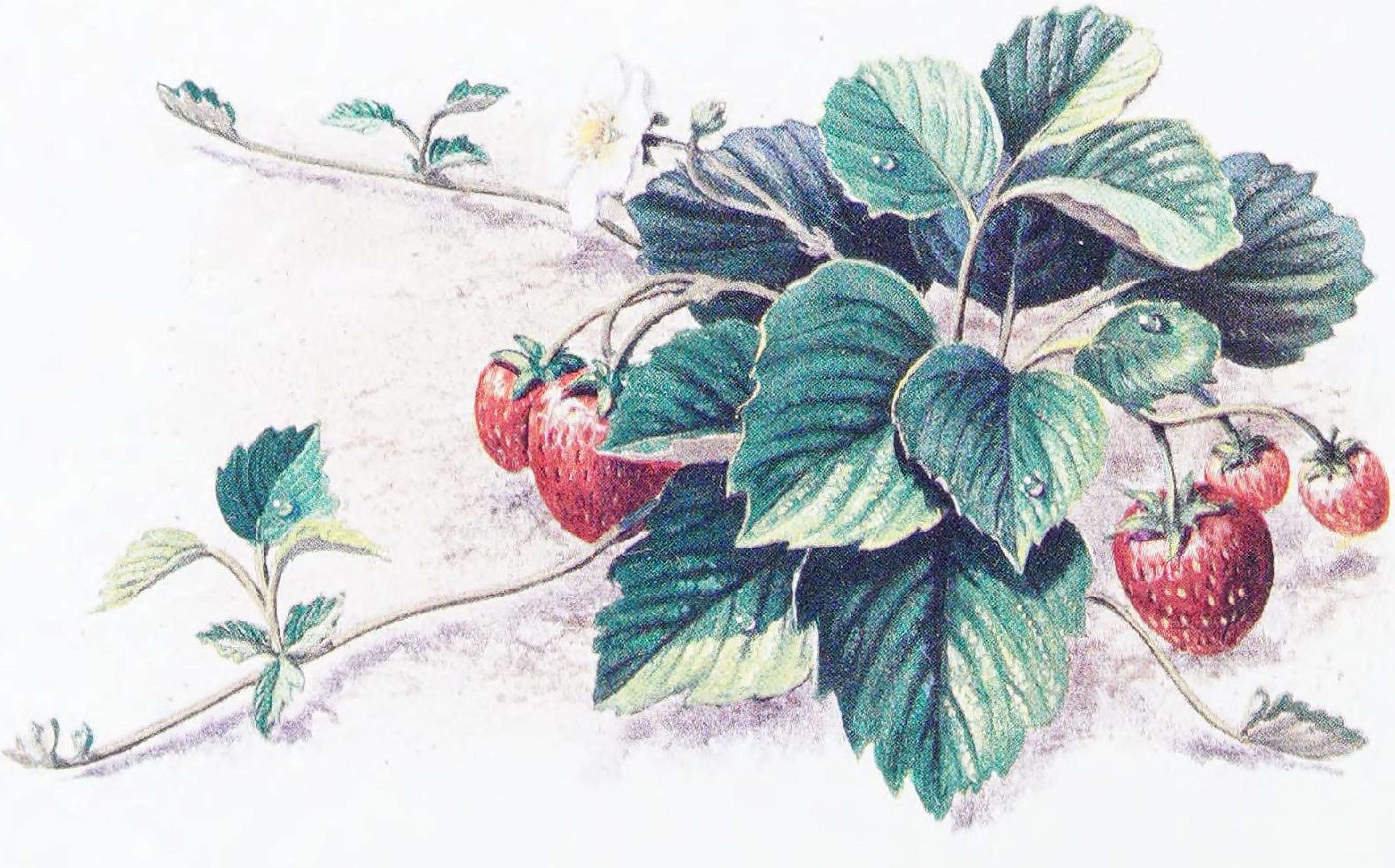


Figure 4-5. Many organisms reproduce asexually. Hydra, above, and strawberry runners, shown right, are examples.

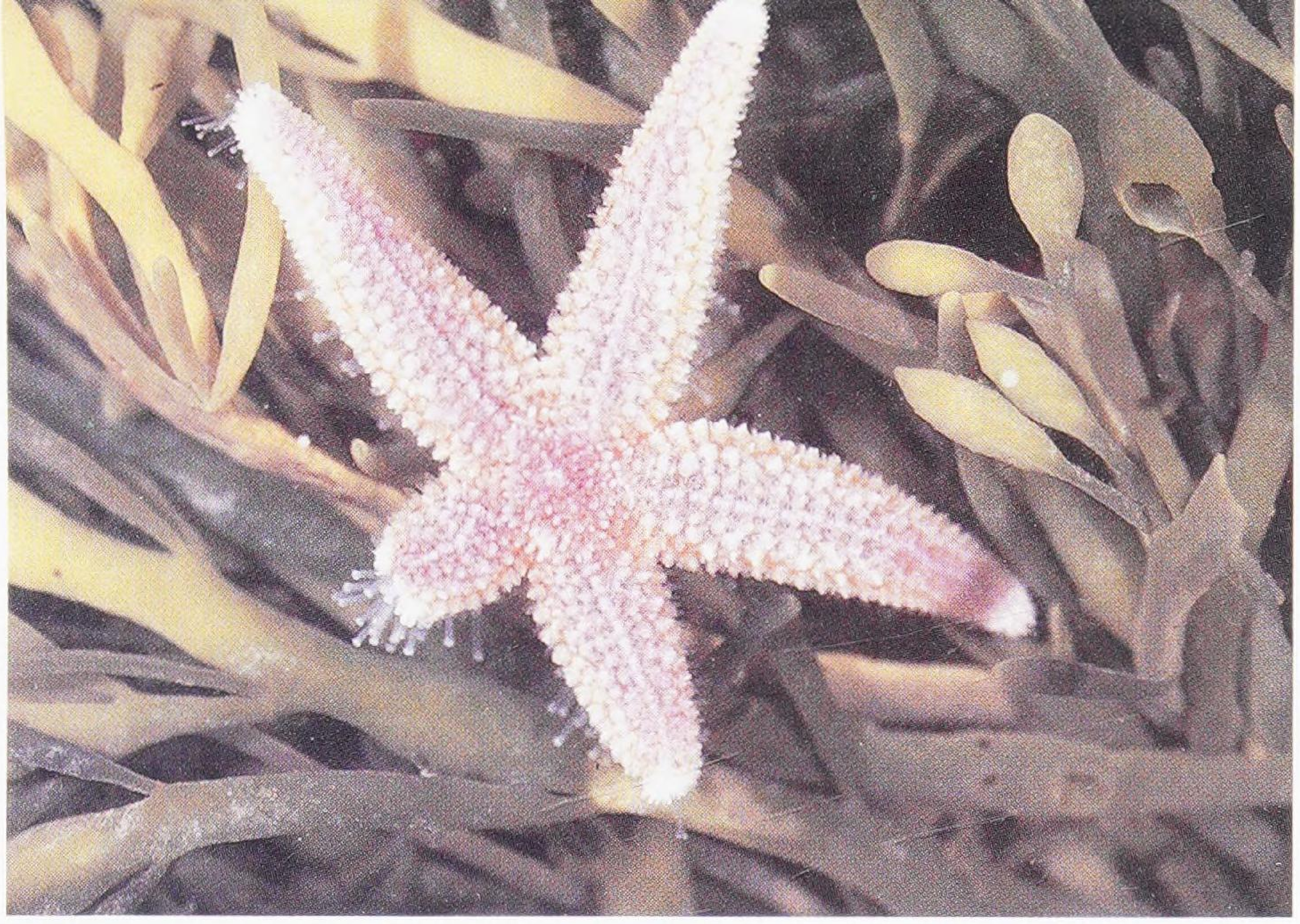


Figure 4-6. Some animals produce whole new body parts by regeneration. A sea star can develop a new ray when one is torn off.

form a whole new sponge body. If a sponge is cut into small pieces, a new sponge develops from each piece. How do you think sponge farmers increase their "crop"?

Through cell division, organisms grow, replace worn-out or damaged cells, or produce whole new organisms. Fission, budding, and regeneration are types of asexual reproduction that result from mitosis.

In **sexual reproduction,** a new organism is produced when sex cells from two parents combine. The DNA of the offspring is different from either parent. You will learn about sexual reproduction in Section 4-2.

Did You Know?

The lining of your digestive system is constantly worn away by the movement of food. Continuous cell division replaces this lining about every five days.

SECTION REVIEW

1. What is mitosis and how does it differ in plants and animals?
2. What are the stages of mitosis?
3. Distinguish between sexual and asexual reproduction.
4. Describe two types of asexual reproduction.
5. **Apply:** The body cells of a frog contain 26 chromosomes. If these cells undergo mitosis, how many chromosomes will be in each new cell produced?
6. **Connect to Chemistry:** Find out what the menstrual cycle is and what is produced during this cycle.

Skill Builder

Outlining

Outline the events in each stage of mitosis in animal cells using the stages of mitosis as heads. Begin with interphase. If you need help, refer to Outlining in the **Skill Handbook** on page 681.

4-2 Sexual Reproduction and Meiosis

New Science Words

sperm
egg
meiosis
fertilization
zygote

Objectives

- Describe the stages of meiosis and its end products.
- Name the cells involved in fertilization and explain how fertilization occurs.

Sexual Reproduction

More than 2000 years ago, people debated how a human could grow from a single egg cell. Some thought the cell must contain a tiny, completely formed human. With the development of the microscope, scientists were able to disprove this idea. With the microscope, they were able to learn more about cells, marvel at reproduction, and watch growth take place.

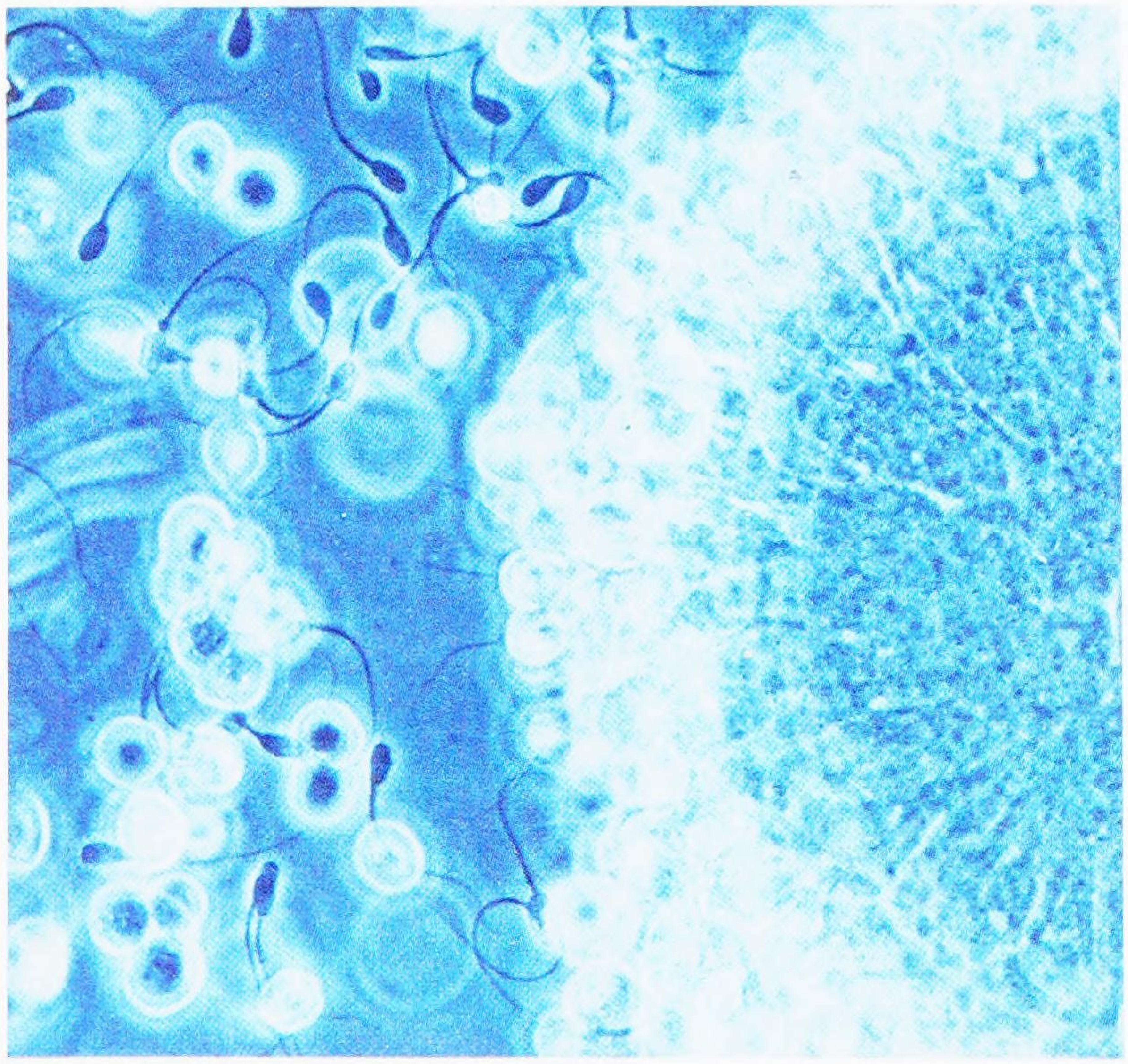


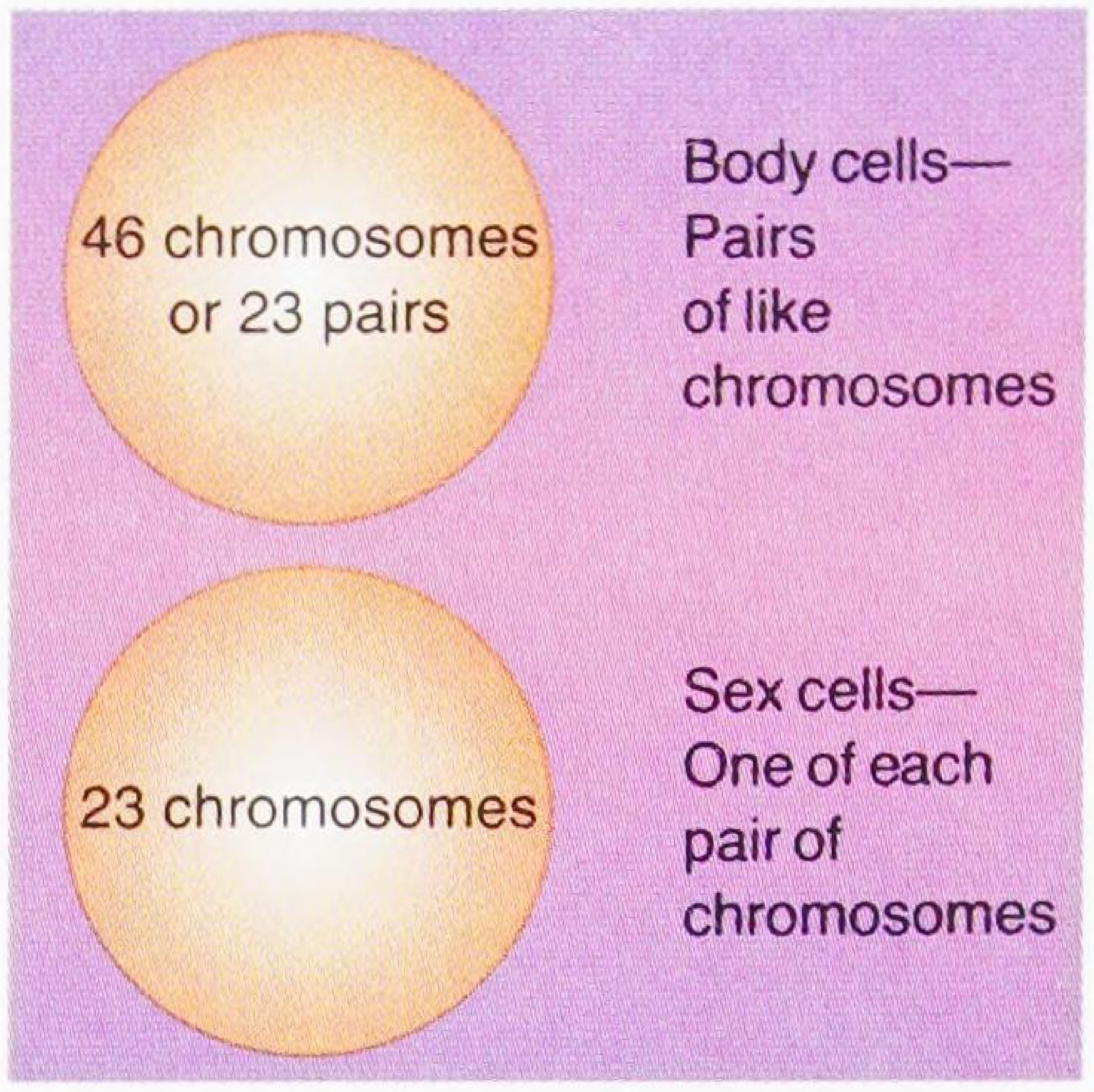
Figure 4-7. The large cell is a human egg cell, or ovum. The smaller cells are human sperm.

In the last section, you learned that asexual reproduction occurs with only one parent. In contrast, sexual reproduction requires two parents to produce offspring. During sexual reproduction two sex cells join to form a new individual. Each sex cell is produced by a different parent. The sex cell from the male parent is called the **sperm.** The sex cell from the female parent is called the **egg.** Sex cells like the ones in Figure 4-7 are usually different in size from one another. Eggs are usually large and contain food material. Sperm are small with whiplike tails. The sperm head is almost all nucleus.

A human body cell has 23 pairs of chromosomes, but human sex cells have only 23 chromosomes. How does the chromosome number become reduced? How do sex cells form? The process of nuclear division that produces sex cells is called **meiosis.** Meiosis takes place in cells of reproductive organs both in plants and animals.

The Importance of Sex Cells

In body cells, chromosomes are found in pairs. The 46 human chromosomes form 23 pairs of chromosomes. The pairs form because the chromosomes are alike. A cell that has two of every kind of chromosome is said to be diploid. Sex cells, on the other hand, contain only one chromosome from each matched pair. A sex cell that has just one chromosome of each pair is haploid. Haploid means "single form." A human sex cell has 23 chromosomes, not 23 pairs of chromosomes. Therefore, it is haploid. For corn, the diploid number is 20, and the haploid number is 10. Usually, the haploid number of chromosomes is found only in sex cells of an organism.


46 chromosomes or 23 pairs
Body cells—Pairs of like chromosomes
23 chromosomes
Sex cells—One of each pair of chromosomes

How many chromosomes will be in a goldfish zygote if the egg of the goldfish contains 94 chromosomes?

What is so important about sex cells? Sexual reproduction starts with the formation of sex cells and ends when one sex cell joins with another and a new organism is begun. The joining of an egg and a sperm is called **fertilization.** The cell that forms in fertilization is called a **zygote.** If an egg with 23 chromosomes joins with a sperm that has 23 chromosomes, a zygote forms that has 46 chromosomes, or the diploid chromosome number for that organism. A zygote then begins to undergo mitosis and the organism develops.

What is fertilization?

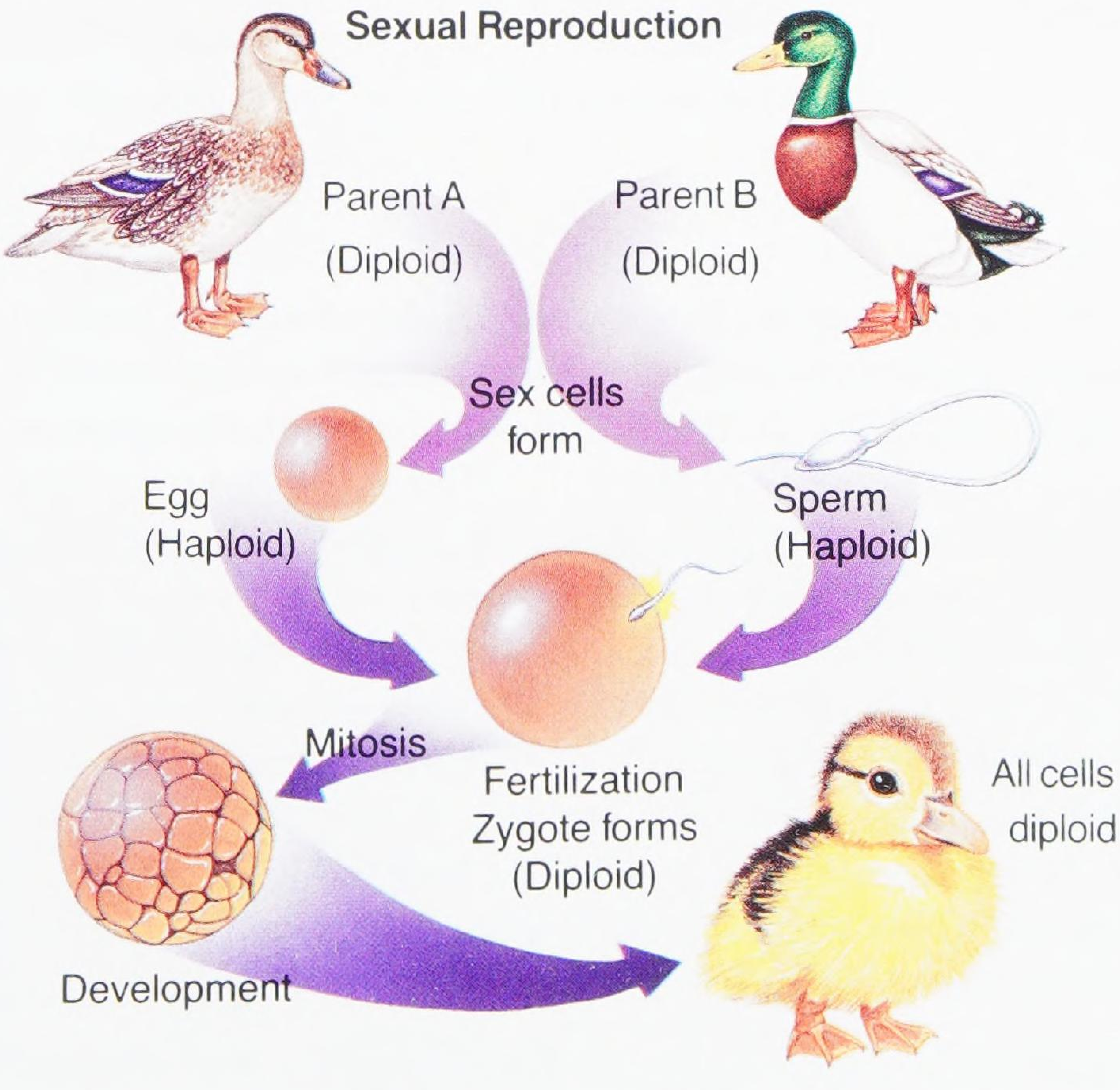

Sexual Reproduction
Parent A
(Diploid)
Parent B
(Diploid)
Sex cells form
Egg
(Haploid)
Sperm
(Haploid)
Mitosis
Fertilization
Zygote forms
(Diploid)
All cells diploid
Development

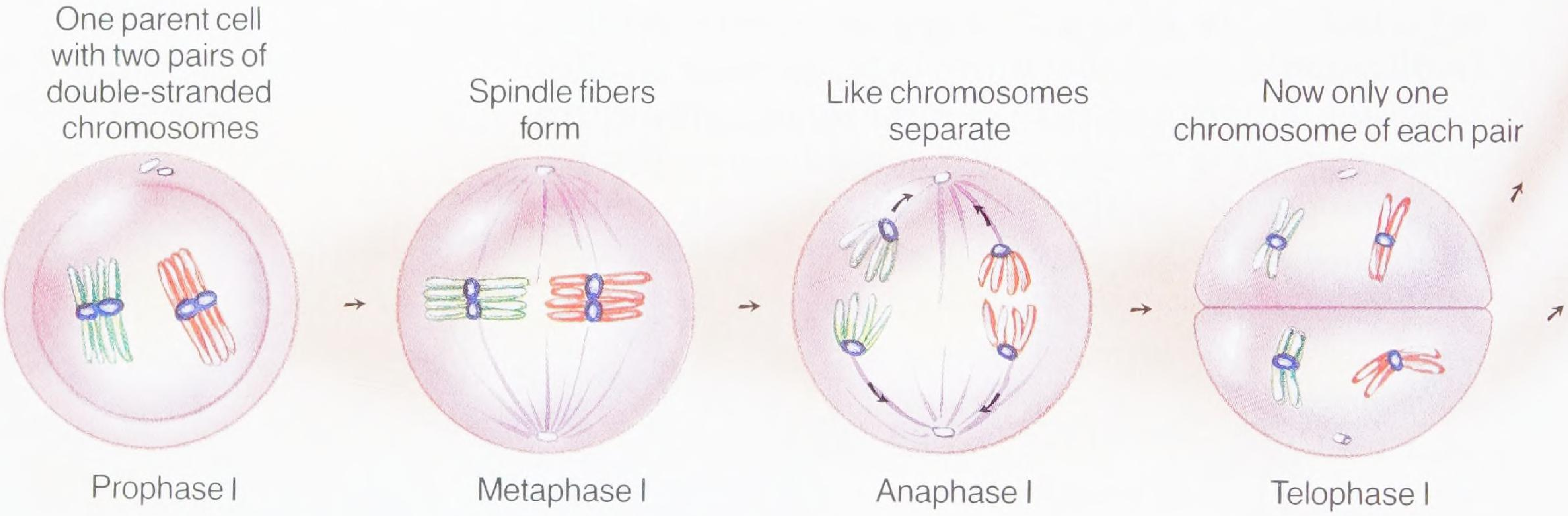
Figure 4-8. When sex cells join, a zygote forms. The zygote develops into a new individual.

Meiosis—Sex Cell Formation

In meiosis, there are two divisions of the nucleus: meiosis I and meiosis II. The different phases of each division have names like those in mitosis, so follow the steps of meiosis I carefully in Figure 4-9. In *prophase I,* double-stranded chromosomes and spindle fibers appear. The nuclear membrane and the nucleolus disappear. Like chromosomes come together in matching pairs.

In *metaphase I,* the pairs of chromosomes line up in the center of the cell. Their centromeres become attached to the spindle fibers. In *anaphase I,* each double-stranded chromosome separates from its matching chromosome. Each one is pulled to opposite ends of the cell. Then in *telophase I,* the cytoplasm divides and two cells form. Each chromosome is still double-stranded.

Figure 4-9. Meiosis begins with the pairing of like chromosomes. The steps of meiosis I are shown on this page.

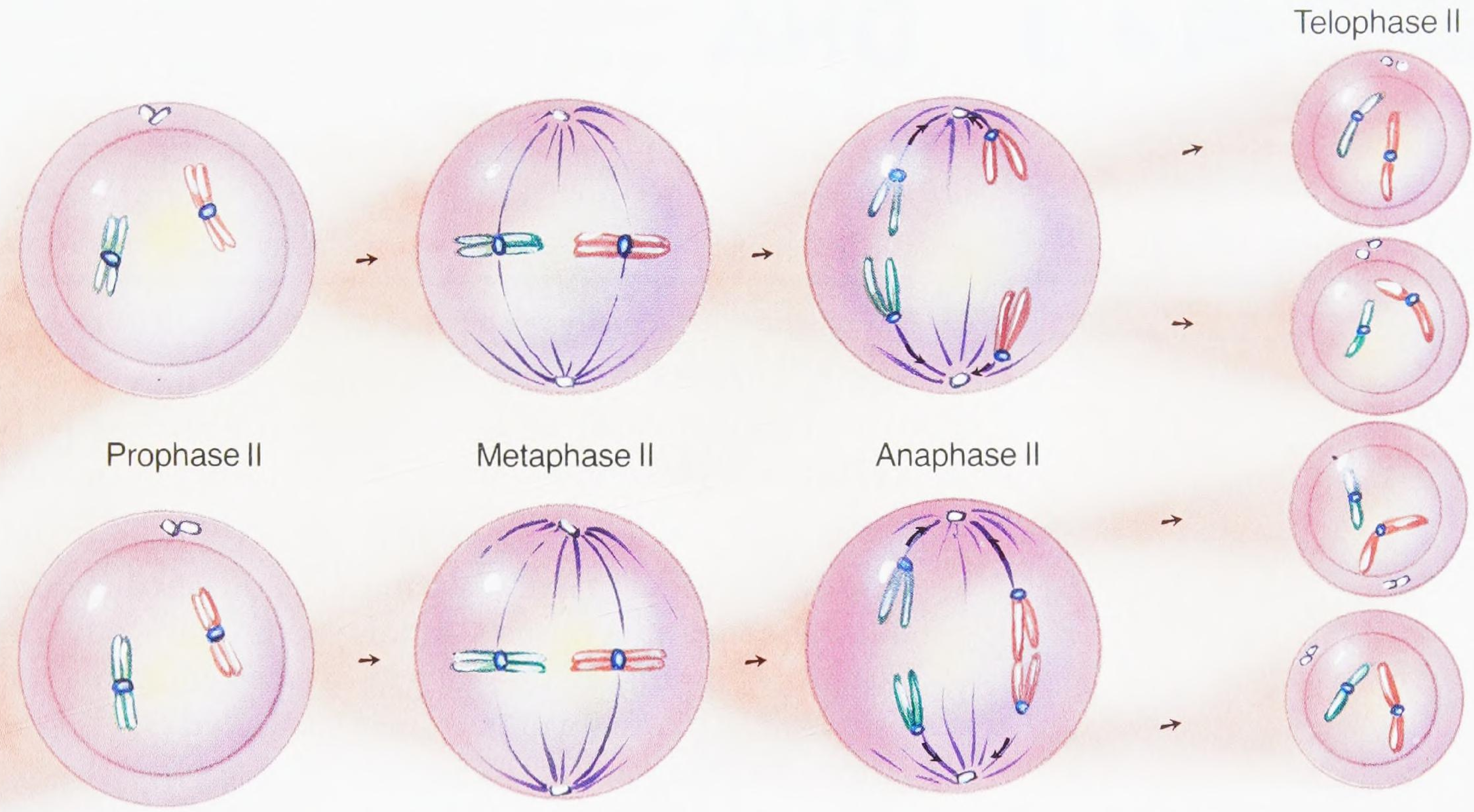

One parent cell with two pairs of double-stranded chromosomes
Spindle fibers form
Like chromosomes separate
Now only one chromosome of each pair
Prophase I
Metaphase I
Anaphase I
Telophase I

Connect to...

Chemistry

The human egg releases a chemical into the surrounding fluid that attracts sperm. Usually only one sperm fertilizes the egg, because after the sperm nucleus enters the egg, the cell membrane of the egg changes, preventing other sperm from entering. What adaptation in this process ensures that the zygote will be just diploid?

Meiosis II begins. In *prophase II,* the double-stranded chromosomes and spindle fibers reappear in each new cell. In *metaphase II,* the double-stranded chromosomes move to the center of the cell. There, the centromeres attach to spindle fibers. During *anaphase II,* the centromere divides, and the two strands of each chromosome separate and move to opposite ends of the cell. As *telophase II* begins, the spindle fibers disappear, and a nuclear membrane forms around the chromosomes at each end of the cell. Each nucleus contains only half the number of chromosomes that were in the original nucleus. A cell with 46 chromosomes at the beginning of meiosis I divides to produce cells that each have only 23 single-stranded chromosomes at the end of meiosis II.



When meiosis II is finished, the cytoplasm divides. Meiosis I forms two cells. In meiosis II, both of these cells divide into two cells. The two nuclear divisions result in four cells. Each of these four cells is a sex cell. Each sex cell has one half the chromosomes as the original cell.

Figure 4-10. The steps of meiosis II are shown. Overall, meiosis results in four sex cells

Are sex cells haploid or diploid?

SECTION REVIEW

1. Why is meiosis I sometimes called reduction division?
2. How many cells are there at the end of meiosis II?
3. What is a zygote, and how is it formed?
4. How do sex cells and body cells differ?
5. **Apply:** If body cells of a horse have 64 chromosomes, how many chromosomes are in a horse sperm cell?
6. **Connect to Physics:** Find out how sperm are stored in sperm banks.

Making and Using Tables

Skill Builder

Make a table to compare mitosis and meiosis in humans. Horizontal heads in your table should be: Feature, Mitosis, and Meiosis. Vertical heads under the Feature column should be: What type of cell (Body or Sex), Beginning cell (Haploid or Diploid), Number of cells produced, End-product cell (Haploid or Diploid), and Number of chromosomes in cells produced. If you need help, refer to Making and Using Tables in the **Skill Handbook** on page 688-689.

4-3 DNA

New Science Words

DNA
gene
RNA
mutation

Objectives

- Construct and identify the parts of a model of a DNA molecule.
- Describe how DNA copies itself.

What Is DNA?

Have you ever sent a message to someone using a code? In order for them to read your message, they had to understand the meaning of the symbols you used in your code. The chromosomes in the nucleus of a cell contain a code. This code is in the form of a chemical called DNA. When mitosis takes place, the DNA code in the nucleus is copied and passed to new cells. In this way, new cells receive the same coded information that was in the original cell. **DNA** controls the activities of cells with coded instructions. Every cell that has ever been formed in your body or in any plant or other animal contains DNA.

Since the mid-1800s, it has been known that the nuclei of cells contain chemicals called nucleic acids. What does DNA look like? Scientist Rosalind Franklin discovered that the DNA molecule was a strand of molecules in a spiral form. By using an X-ray technique, Dr. Franklin showed that the spiral was so large that it was probably made up of two spirals. As it turned out, the structure of DNA is similar to the handrails and steps of a spiral staircase. In 1953, using the work of Franklin and others, scientists James Watson and Francis Crick made a model of a DNA molecule. According to the Watson and Crick model, the sides ("the handrails") of the DNA molecule are made up of two twisted strands of sugar and phosphate molecules. The

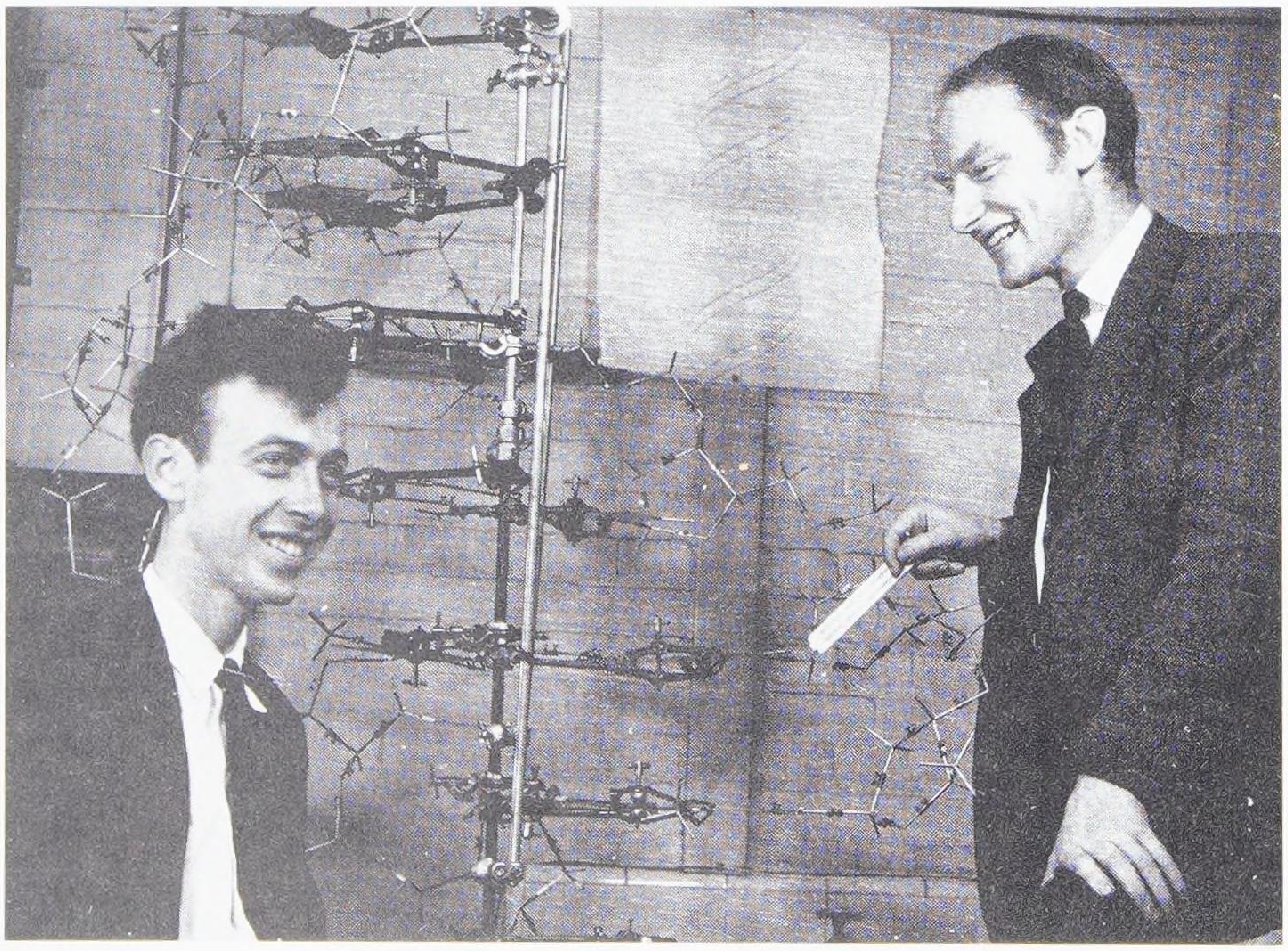
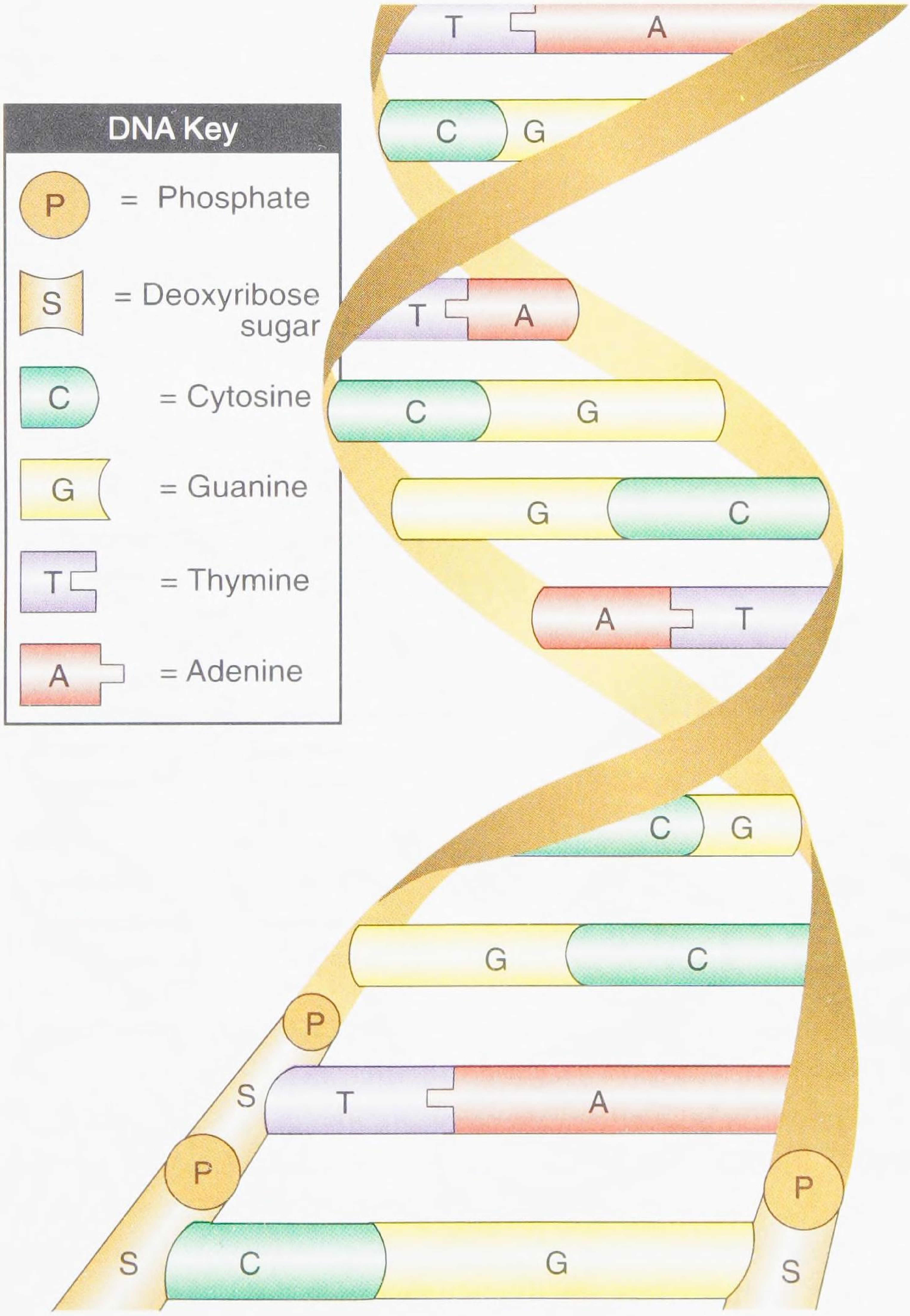


Figure 4-11. James Watson and Francis Crick with their model of DNA.

"stairs" that hold the two sugar-phosphate strands apart are made up of molecules called nitrogen bases. There are four kinds of nitrogen bases. These are adenine, guanine, cytosine, and thymine. In Figure 4-12, the bases are represented by the letters *A, G, C,* and *T.* An American biochemist named Edwin Chargaff had discovered in 1949 that the amount of cytosine in cells always equals the amount of guanine and that the amount of adenine always equals the amount of thymine. This led him to hypothesize that these bases occur in pairs in the molecule. The Watson and Crick model shows that adenine always pairs with thymine, and guanine always pairs with cytosine. Like interlocking pieces of a puzzle, each base pairs up only with its correct partner.

In Your JOURNAL

Read about the life and work of at least four people who contributed to the discovery of DNA. **In your Journal**, write a paragraph about the contribution of each one.



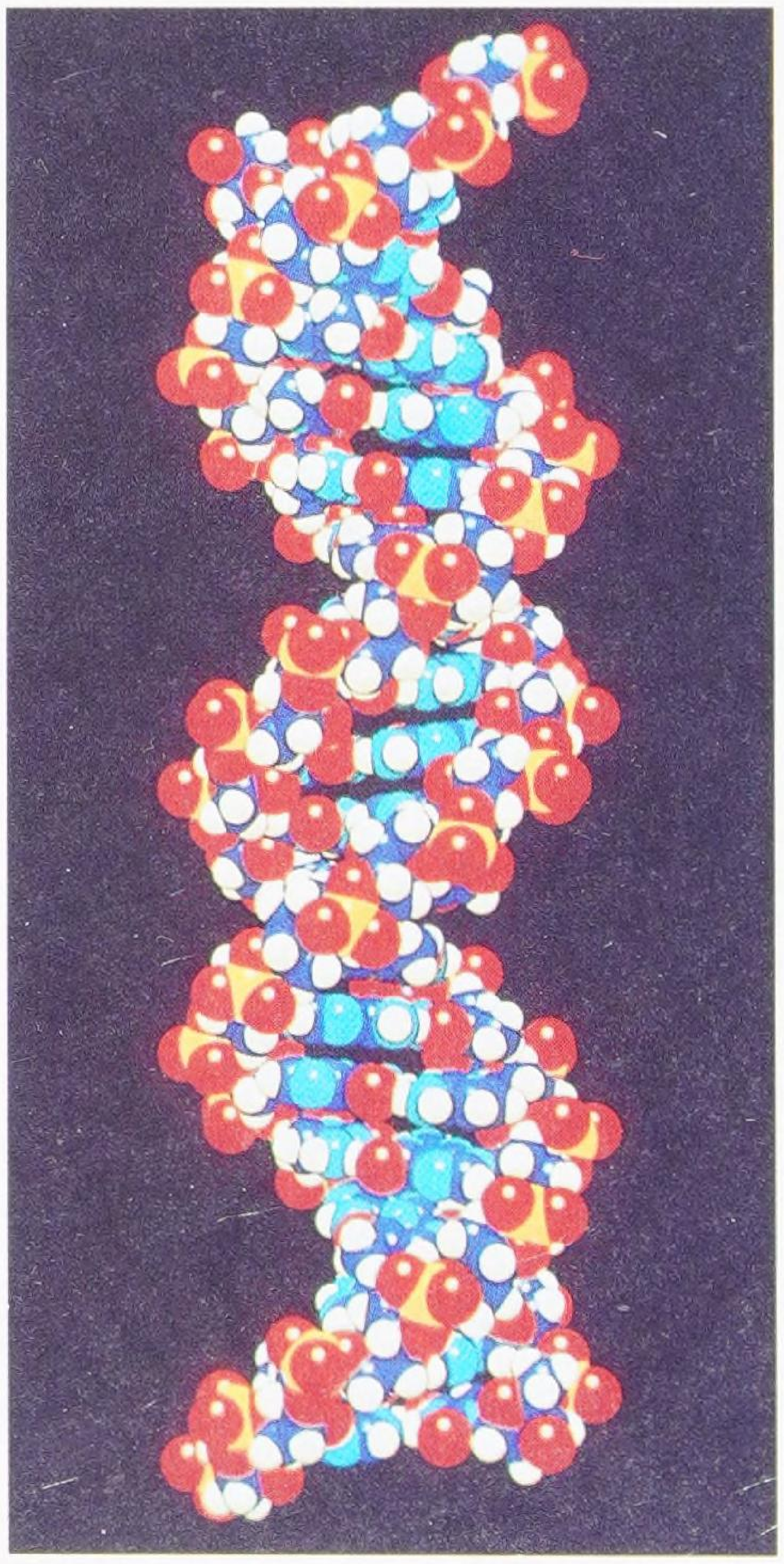


Figure 4-12. DNA stands for *de*oxyribo*n*ucleic *a*cid. Two models of the DNA molecule and its parts are shown.

Connect to...

Physics

X rays, a form of electromagnetic radiation, have provided valuable information for research and health. Name three things that X rays can be used for.

How DNA Copies Itself

When chromosomes are doubled at the beginning of mitosis, the amount of DNA in the nucleus is also doubled. What is the process by which DNA copies itself? The Watson and Crick model can be used to show how this takes place. The two strands of DNA unwind and separate. Each strand then becomes a pattern on which a new strand is formed. Figure 4-13 follows a strand of DNA as it produces two new DNA strands identical to the original DNA. The events that take place while DNA copies itself are given below.

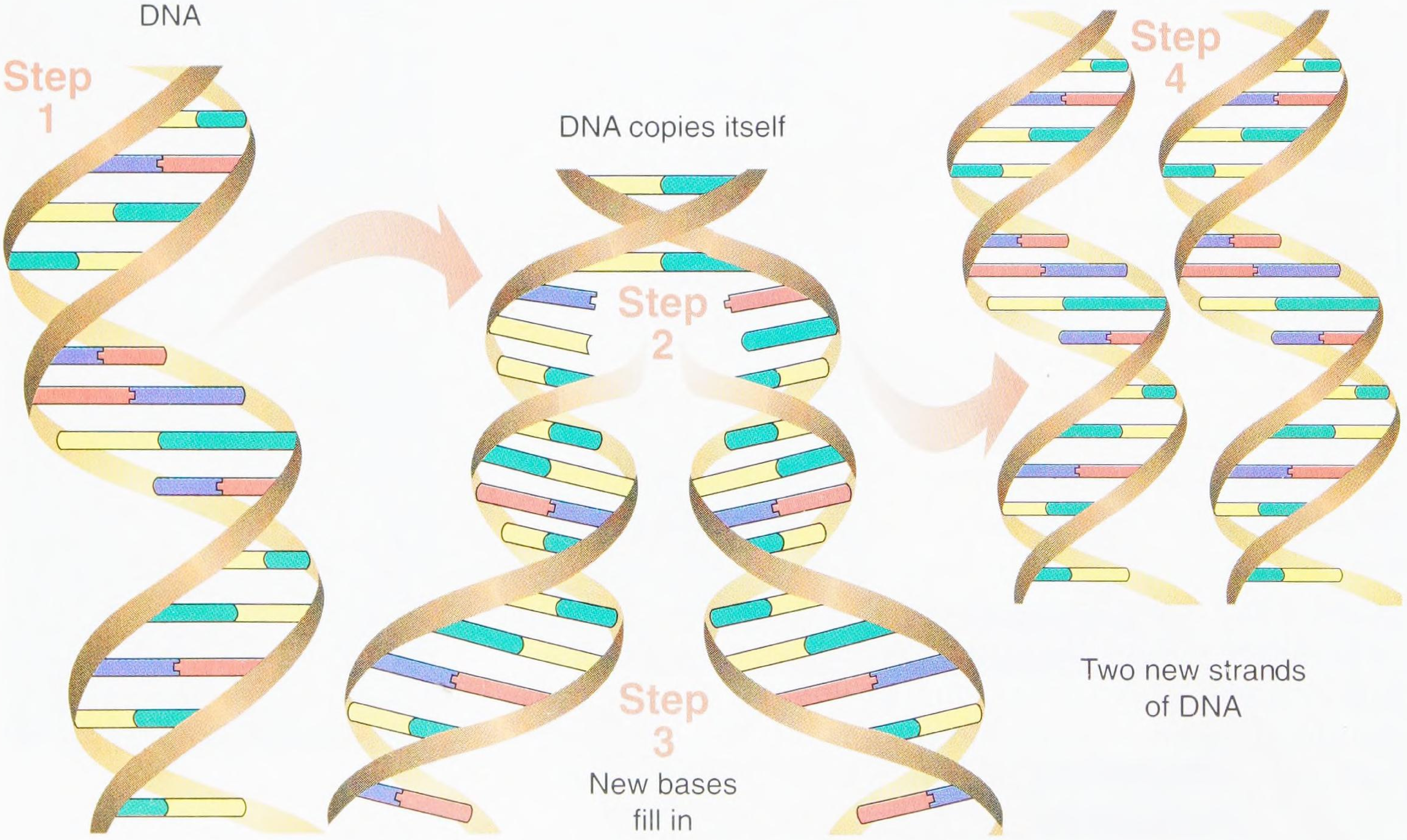
Step 1. DNA molecule before copying begins

Step 2. An enzyme breaks the bonds between the nitrogen bases. The two strands of DNA separate.

Step 3. The bases attached to each strand then pair up with new bases from a supply found in the cytoplasm. Adenine pairs with thymine. Cytosine pairs with guanine. The order of base pairs in each new strand of DNA will match the order of base pairs in the original DNA.

Step 4. Sugar and phosphate groups form the side of each new DNA strand. Each new DNA molecule now contains one strand of the original DNA and one new strand.

Figure 4-13. DNA uses itself as a pattern when it is copied.



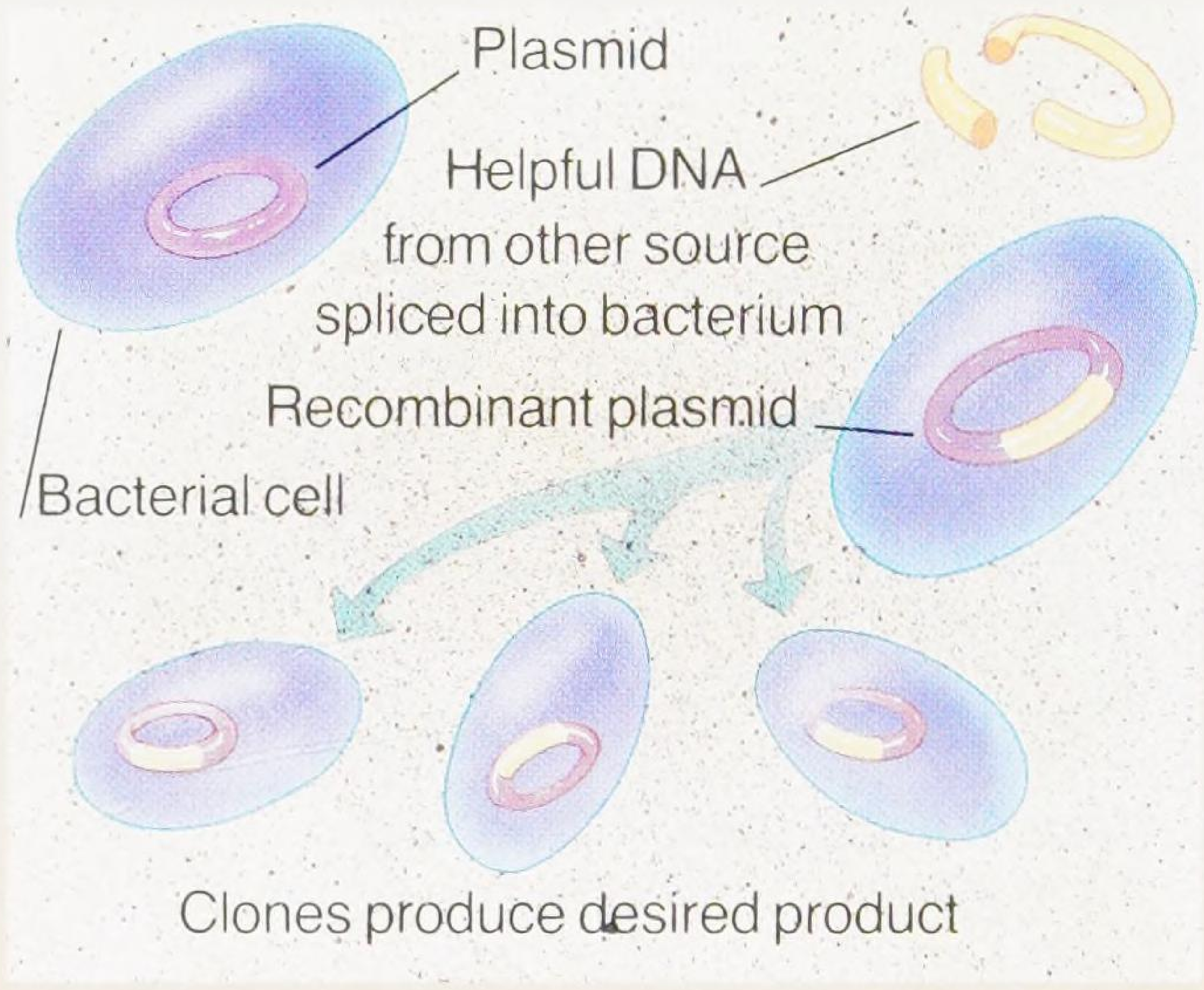
TECHNOLOGY

The Bacteria Factory

Bacteria can be turned into factories to produce important substances using DNA technology. Small circular molecules in some bacteria, called plasmids, are the key. A piece of DNA from another source is joined or spliced to the plasmid. This modified plasmid is mixed with bacterial cells and a few take in the new plasmid. Quickly, each cell grows into a colony of millions of cells—each producing the desired substance.

Insulin for diabetics and enzymes for making cheese have become common products of DNA technology. With the help of this technology, sugars in vegetable wastes have been converted into ethanol, a clean-burning fuel.

Think Critically: How would bacteria-produced ethanol be useful in the United States?


Plasmid
Helpful DNA from other source spliced into bacterium
Recombinant plasmid
Bacterial cell
Clones produce desired product

DNA and Genes

Why is DNA important? All of the characteristics that you have are affected by the DNA that you have in your cells. It controls the color of your eyes, the color of your hair, and whether or not you can digest milk. These characteristics are called traits. How traits appear in you depends on the kinds of proteins your cells make. DNA stores the blueprints for making proteins.

Proteins are made of units called amino acids that are linked together in a certain order. A protein may be made of hundreds or thousands of amino acids. Changing the order of the amino acids changes the kind of protein made. The section of DNA on a chromosome that directs the making of a specific protein is called a **gene.** Genes control proteins that build cells and tissues and work as enzymes. Think about what might happen if an important protein couldn't be made in your cells.

What is a gene?

How does a cell know which proteins to make? The gene gives the directions for the order in which amino acids will be arranged. This order results in a particular protein.

MINI-Lab

How is RNA made?

RNA is made in the nucleus on a pattern supplied by DNA. Look at Figures 4-12 and 4-13 to see the structure of DNA and how these strands separate to make new DNA. When RNA is made, the two DNA strands separate and one is used as a pattern for making a strand of RNA. Suppose a molecule of DNA untwists and separates and the left strand is used to make RNA. If the order of the bases in the DNA strand is T C A G A T C G A, what, in correct order, will be the bases in the RNA? If the new strand of RNA that you just made were a piece of mRNA, what tRNA bases would link up with it in the cytoplasm?

In Chapter 2, you learned that proteins are made on ribosomes in cytoplasm. How does the code in the nucleus reach the ribosomes out in the cytoplasm? The codes for making proteins are carried from the nucleus to the ribosomes by a second type of nucleic acid, called ribonucleic acid or **RNA**. RNA is different from DNA in that it is made up of only one strand, and it contains a nitrogen base called uracil (U) in place of thymine. RNA is made in the nucleus on a DNA pattern.

Two different kinds of RNA are made from DNA in the nucleus—messenger RNA (mRNA) and transfer RNA (tRNA). Protein assembly begins as mRNA moves out of the nucleus and attaches to ribosomes in the cytoplasm. Pieces of tRNA pick up amino acids in the cytoplasm and bring them to the ribosomes. There, tRNA temporarily matches with mRNA and the amino acids become arranged according to the code carried by mRNA. The amino acids become bonded together, and a protein molecule begins to form.

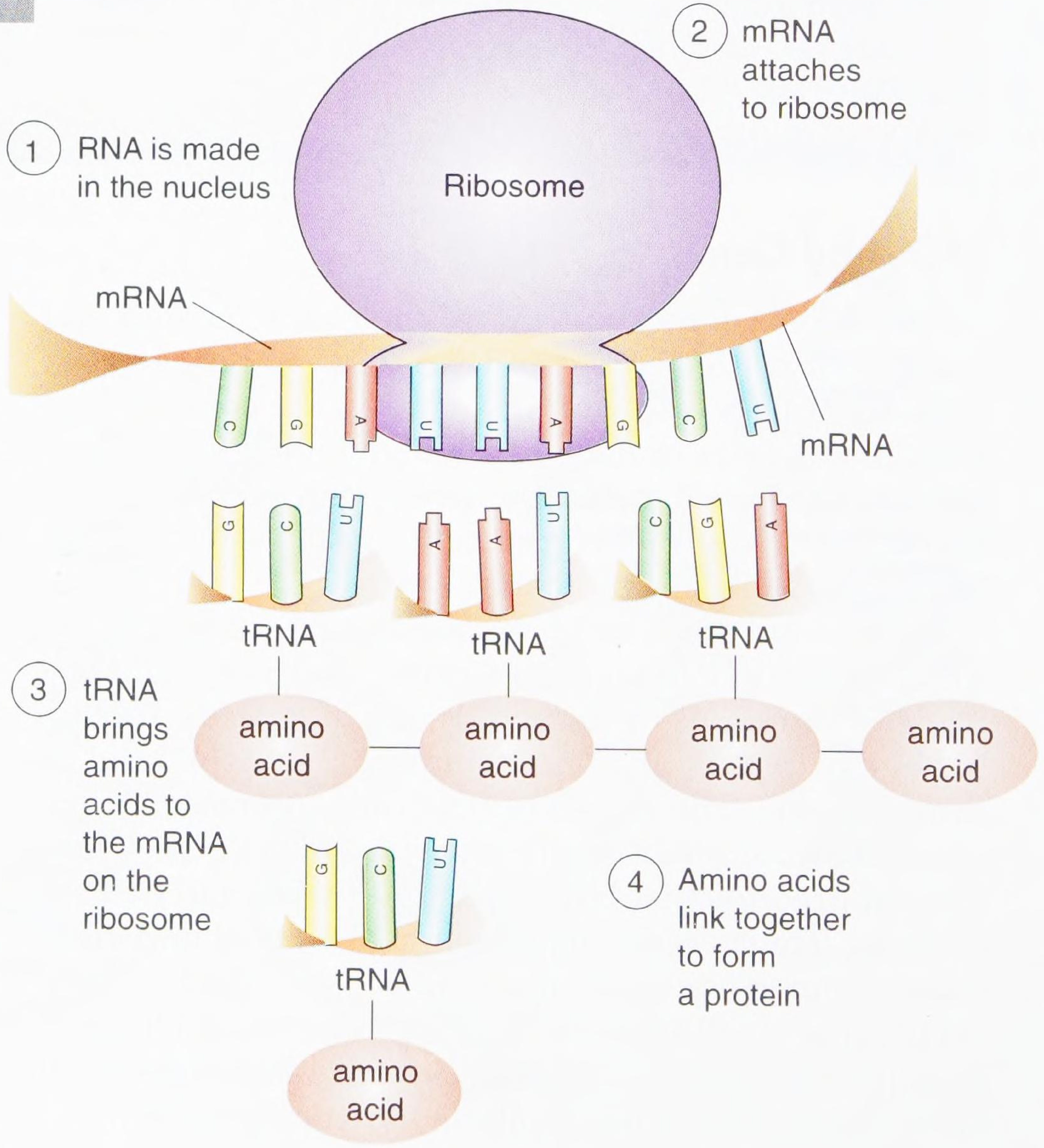

② mRNA attaches to ribosome
① RNA is made in the nucleus
Ribosome
mRNA
C
G
A
U
U
A
G
C
U
mRNA
G
C
U
A
A
U
C
G
A
tRNA
tRNA
tRNA
③ tRNA brings amino acids to the mRNA on the ribosome
amino acid
amino acid
amino acid
amino acid
G
C
U
tRNA
amino acid
④ Amino acids link together to form a protein

Figure 4-14. RNA carries the code for a protein from the nucleus to the ribosome. There, its message is translated into a specific protein.

Mutations

Genes control the traits you inherit. Without correctly coded proteins, an organism can't grow, repair, or maintain itself. If a change occurs in a gene or chromosome, the traits of that organism are changed. Sometimes during replication an error is made in copying a gene. Occasionally, a cell receives an entire extra chromosome. Outside factors such as X rays and chemicals have been known to change or break chromosomes. Any permanent change in a gene or chromosome of a cell is called a **mutation.** If the mutation occurs in a body cell, it may or may not be life threatening to the organism. If, however, a mutation occurs in a sex cell, then all the cells that are formed from that sex cell will have that mutation. Down syndrome in humans occurs when a sex cell forms with an extra number 21 chromosome, so that the zygote that forms has three number 21 chromosomes. Many mutations are harmful to organisms. Some are not. Many times, an organism with a mutation doesn't survive. But mutations also add variety to a species.

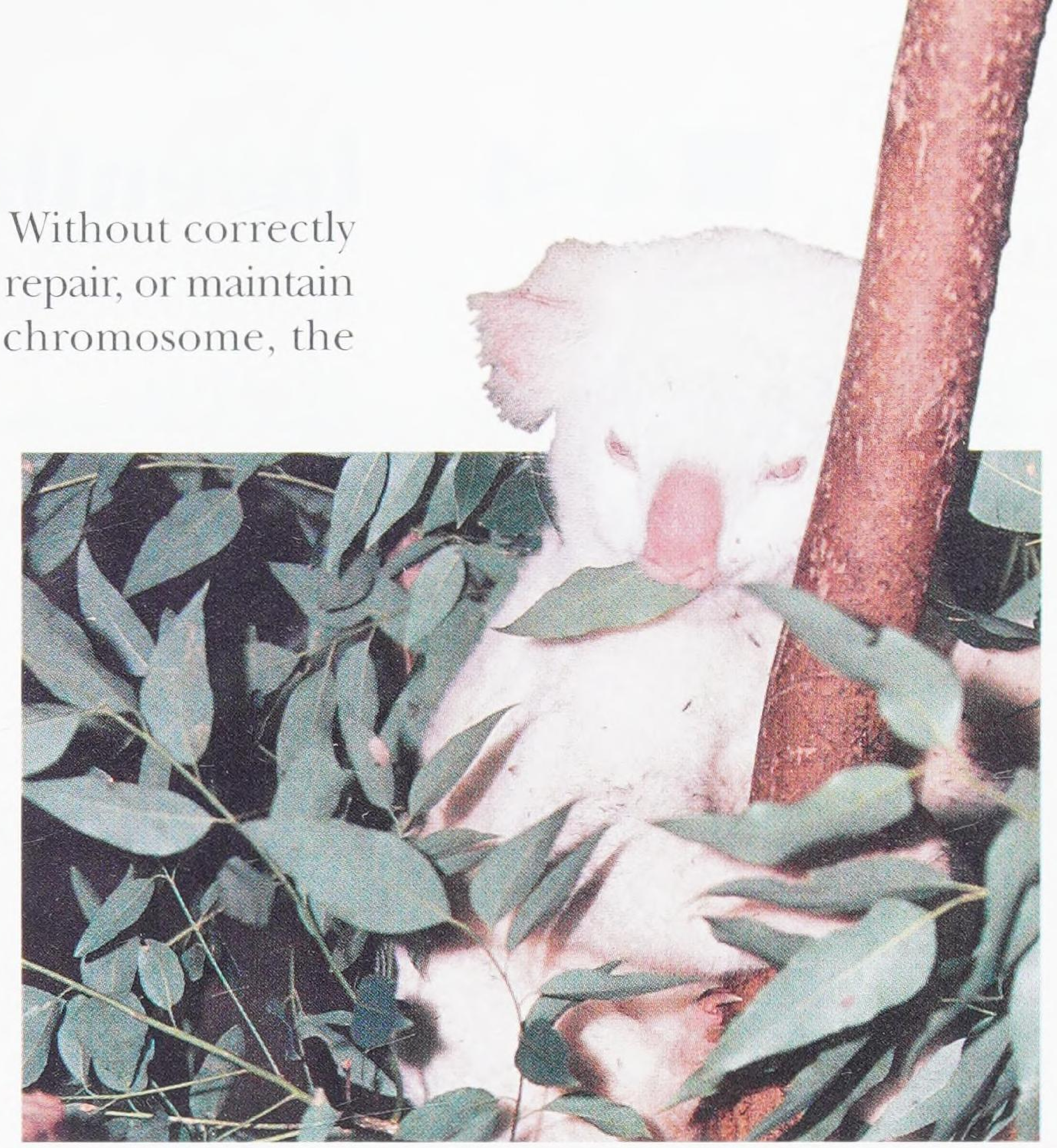


Figure 4-15. Albinism, resulting in the lack of pigments in skin, eyes, and hair, is an example of a mutation.

SECTION REVIEW

1. Which bases form pairs in a DNA molecule?
2. Why is protein production important in a cell?
3. How does DNA make a copy of itself?
4. **Apply:** A single strand of DNA has the bases AGTAAC. Using letters, show what bases would match up to form a matching DNA strand from this pattern.
5. **Connect to Chemistry:** Strands of DNA are held together by hydrogen bonds. What is the atomic number of hydrogen?

Concept Mapping

Skill Builder

Using a network tree concept map, show how DNA and RNA are alike and how they are different. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

SCIENCE & SOCIETY

4-4 Inventing Organisms

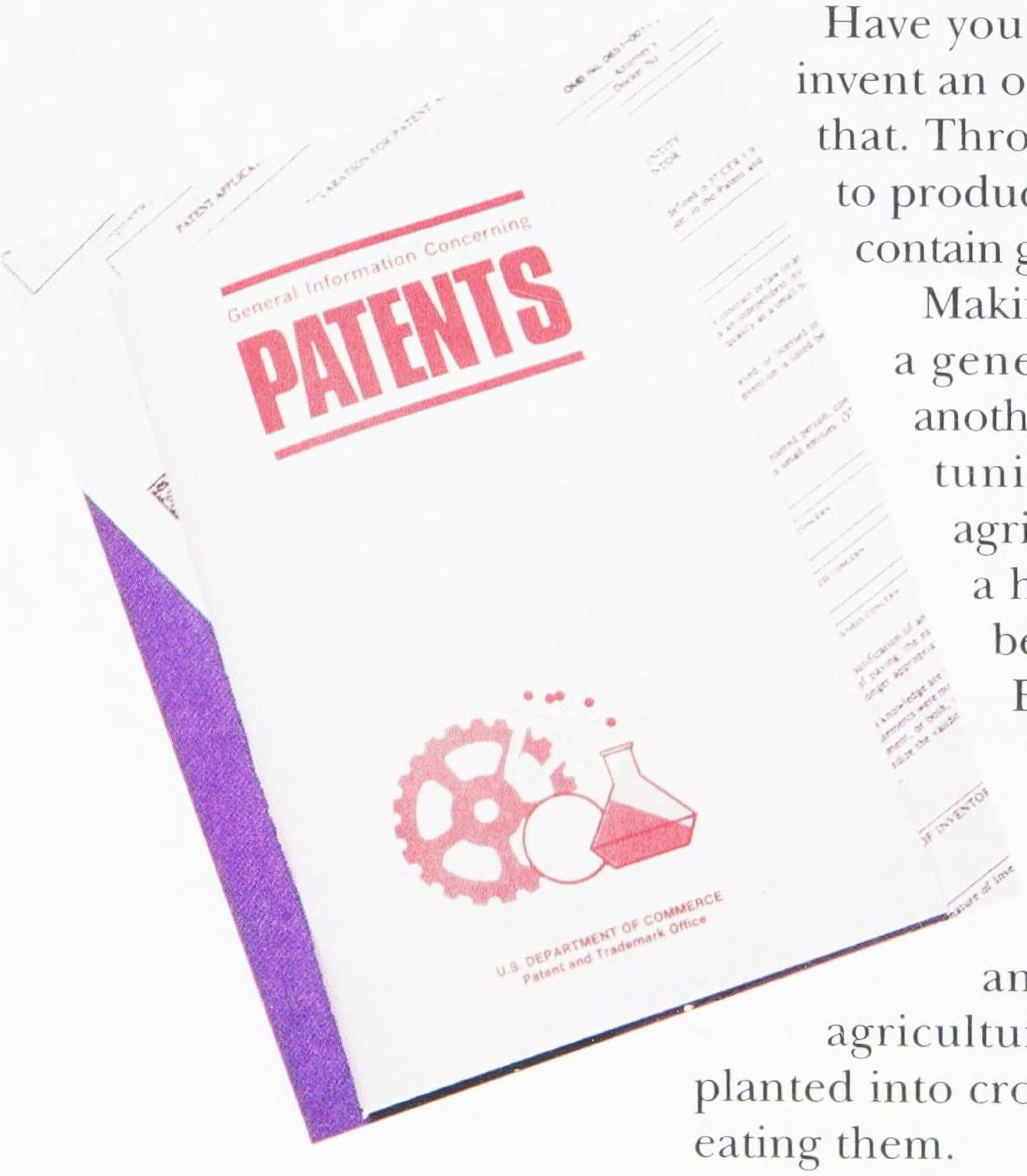
New Science Words

transgenic organisms

Objectives

- Explain the term *transgenic organism.*
- Explain some advantages and disadvantages of patenting organisms.

Transgenic Organisms

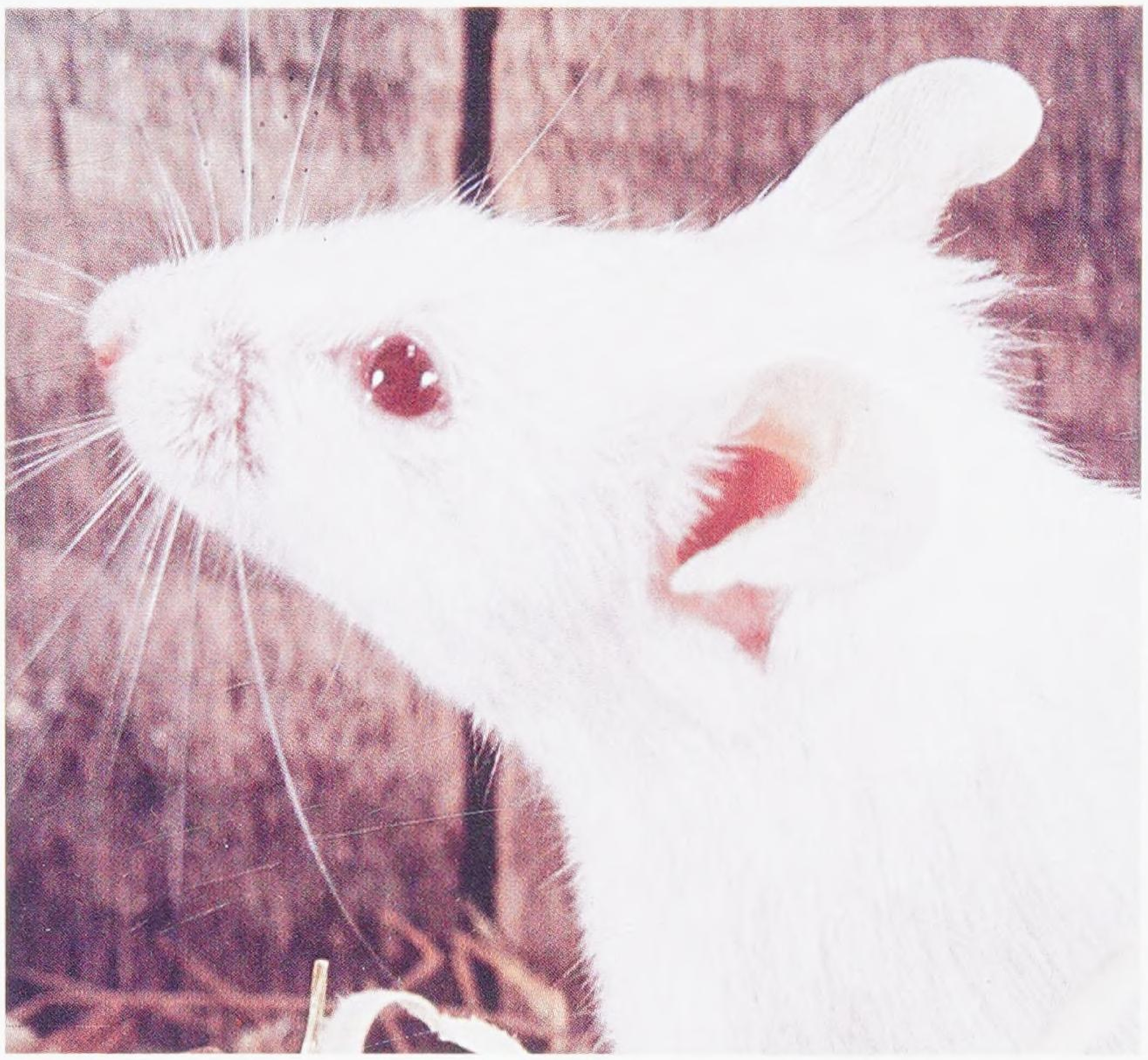

General Information Concerning
PATENTS
U.S. DEPARTMENT OF COMMERCE
Patent and Trademark Office

Have you ever thought of actually being able to invent an organism? Today, scientists are doing just that. Through genetic engineering, they are able to produce **transgenic organisms,** organisms that contain genetic information from another species. Making a transgenic organism involves taking a gene from one organism and placing it in another. This technology provides many opportunities for research in medicine and agriculture. For example, a mouse received a human gene that resulted in the animal being very susceptible to human cancers. Because this mouse can develop certain types of tumors, it is a very valuable tool for cancer research. Using this organism, tests can be conducted to detect substances that cause cancer. Potential anti-cancer drugs can also be tested. In agriculture, a gene from bacteria can be transplanted into crops to prevent certain insect pests from eating them.

Patenting Life

Biologists are now asking for patents on genetically engineered organisms that they develop in the laboratory. A patent is a license issued by the government that gives the owner the legal right to control the manufacture and sale of an invention. In 1988, the United States government gave the first transgenic organism patent to Harvard University for its transgenic mouse.

The development of transgenic organisms and the patenting of these organisms have met some opposition. People who are concerned about the consequences of such genetic technology worry that transgenic organisms may become pests or burdens to society. Some think that transgenic plants and animals might have the same effect on society as organisms introduced into the United States from other countries. Certain species of plants and insects have taken over or destroyed many native organisms. In addition, many people are opposed to the idea of having legal ownership of living organisms. Although the patents are designed to protect the biotechnology industry, some scientists see patenting of organisms as a barrier to the tradition of sharing information within the scientific community.



As technology continues to grow and play an important role in society, new developments may present new risks to the environment. People will have to compare these risks with the benefits that they may provide.

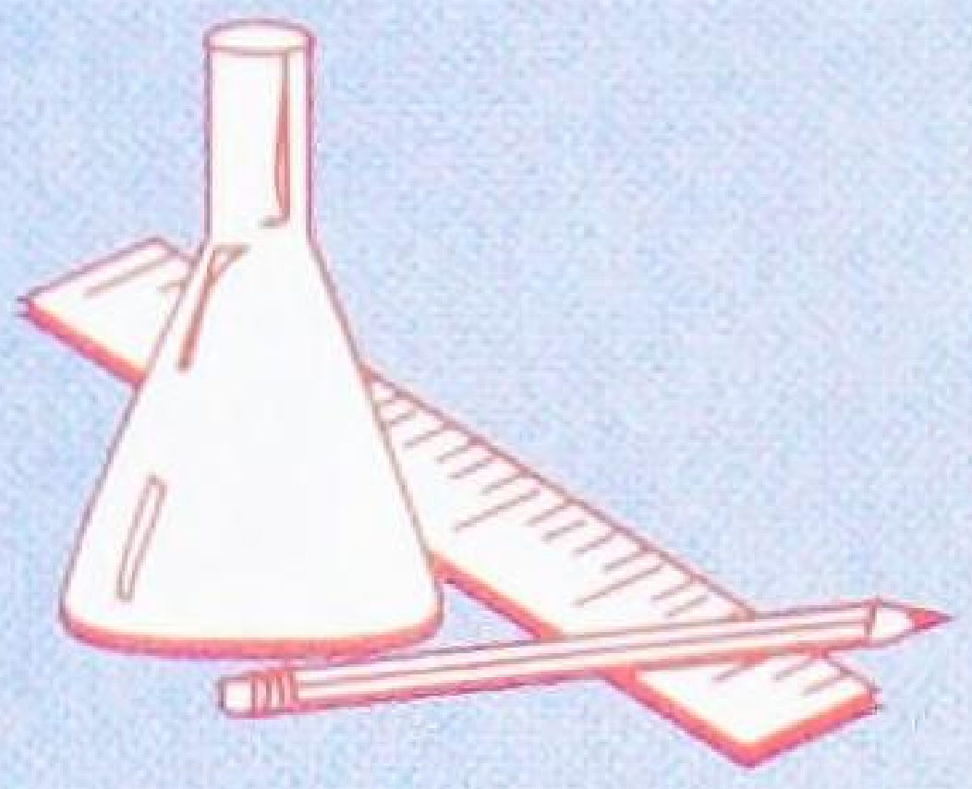
SECTION REVIEW

1. What is a transgenic organism?
2. List two risks of developing transgenic organisms.
3. What rights does a patent owner have?

SCIENCE & SOCIETY

You Decide!

After hospital patients have had surgery to remove tumors or tissues, these cells are sometimes saved. They are kept alive in the laboratory. Sometimes these cells, or products made from these cells, are sold for use in research. Patients are now claiming that they should have profits from products made from their own body tissues. Research companies that develop the products disagree. They argue that the cells all by themselves are useless without the time and skills of the researchers. Should patients be paid for products made from their cells?



ACTIVITY 4-2

Making a Model

Problem: *What does a model of DNA look like?*

Materials

- tracing paper
- scissors
- heavy paper
- crayons

Procedure

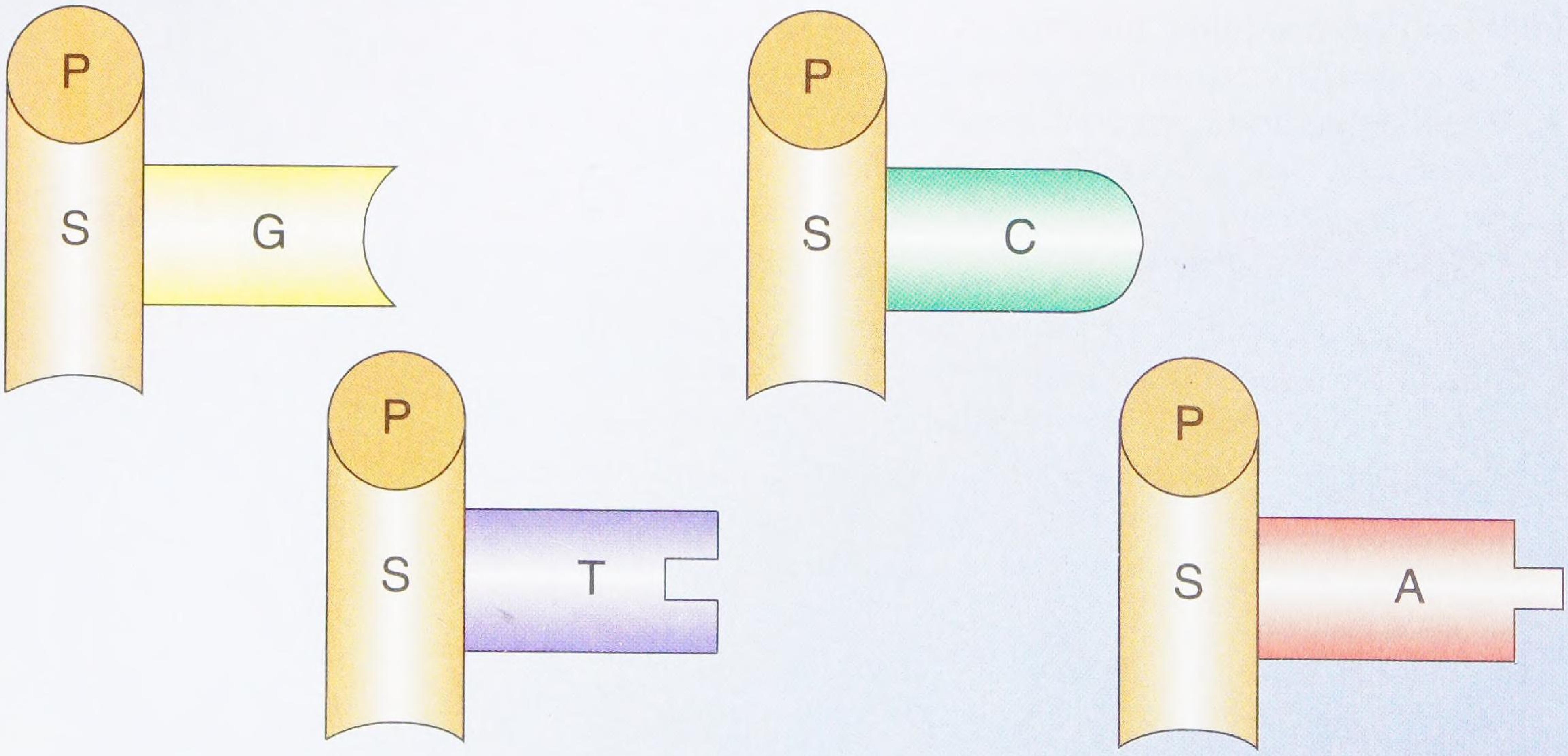
1. Trace the four DNA parts shown below.
2. Cut out the four tracings. **CAUTION:** *Always be careful when using scissors.*
3. Copy each of the tracings onto heavy paper six times. Label each tracing as shown below.
4. Color the phosphate brown. Color the sugar orange. Color the A bases red, the T bases blue, the C bases green, and the G bases yellow.
5. Cut out all 24 parts.
6. Use the following order of bases to *model* a DNA molecule: ATCCGT. Use your desk as a work space.
7. Separate the bases in the molecule and replicate the original molecule.
8. Use any combination of DNA parts to create other model molecules. Compare your molecules with those of your classmates.

Analyze

1. What does each DNA part represent?
2. What does the A base pair with?
3. What does the C base pair with?
4. What is the order of bases in the second strand of the DNA molecule in Step 6?
5. Were the molecules you created in Step 8 the same as your classmates'? Explain.

Conclude and Apply

6. Using the model, explain why T only matches with A.
7. Based on your observations of the DNA model, *infer* why a DNA molecule seldom copies itself incorrectly.
8. Explain why scientists use models.



CHAPTER REVIEW

SUMMARY

4-1: Cell Growth and Division

1. Cells divide to form new cells by mitosis and divisions of cytoplasm. There are four stages of mitosis, during which chromosomes copy themselves, separate, and become part of new nuclei.

2. Animal cells have centrioles. New animal cells form when the cytoplasm pinches in. Plant cells lack centrioles; cytoplasm is separated by a cell plate following mitosis.

3. Asexual reproduction requires only one parent. Sexual reproduction requires two parents to produce a new individual. Fission, budding, and regeneration are all methods of asexual reproduction.

4-2: Sexual Reproduction and Meiosis

1. Sexual reproduction involves the production of sex cells through the process of meiosis.

2. Sex cells from two parents fuse during fertilization to produce a zygote, a cell with the diploid chromosome number.

3. Meiosis is a division of nuclei in reproductive cells that results in sex cells, four cells with the haploid chromosome number.

4-3: DNA

1. DNA is made up of bases that appear in specific sequences, and it directs all activities of a cell. DNA can copy itself and is the framework on which RNA is made.

2. RNA assembles proteins in the cytoplasm based on instructions from genes in the nucleus.

3. Mutations are changes in an organism's DNA. Most are harmful to the organism, but some are known to be beneficial.

4-4: Science and Society: Inventing Organisms

1. Transgenic organisms contain genes from an organism of another species.

2. Transgenic organisms can be used in research, but may become pests in nature.

KEY SCIENCE WORDS

a. **asexual reproduction**
b. **chromosomes**
c. **DNA**
d. **egg**
e. **fertilization**
f. **gene**
g. **meiosis**
h. **mitosis**
i. **mutation**
j. **RNA**
k. **sexual reproduction**
l. **sperm**
m. **transgenic organisms**
n. **zygote**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. nuclear structures containing DNA
2. new individuals are identical to parent organism
3. segments of DNA that control traits
4. deoxyribonucleic acid
5. formation of two new nuclei with identical chromosomes
6. fusion of an egg and a sperm
7. nuclear division that forms sex cells
8. a permanent change in a cell's DNA
9. an organism containing genetic information from another species
10. nucleic acid that carries information for making proteins from the nucleus

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. ______ is a double spiral molecule with pairs of nitrogen bases.
   - **a.** RNA
   - **b.** An amino acid
   - **c.** A protein
   - **d.** DNA
2. RNA differs from DNA in that it contains ______.
   - **a.** thymine
   - **b.** thyroid
   - **c.** adenine
   - **d.** uracil
3. If a diploid tomato cell with 24 chromosomes undergoes meiosis, the sex cells produced will each have ______ chromosomes.
   - **a.** 6
   - **b.** 12
   - **c.** 24
   - **d.** 48
4. Chromosomes are doubled during ______.
   - **a.** anaphase
   - **b.** metaphase
   - **c.** interphase
   - **d.** telophase
5. During ______ in mitosis, double-stranded chromosomes separate.
   - **a.** anaphase
   - **b.** prophase
   - **c.** metaphase
   - **d.** telophase
6. The chromosome number in cells after mitosis is ______ the parent cell number.
   - **a.** the same as
   - **b.** half
   - **c.** twice
   - **d.** four times
7. Budding, fission, and regeneration are forms of ______.
   - **a.** mutations
   - **b.** cell cycles
   - **c.** sexual reproduction
   - **d.** asexual reproduction
8. ______ is any permanent change in a gene or a chromosome.
   - **a.** Fission
   - **b.** Reproduction
   - **c.** Replication
   - **d.** Mutation
9. Meiosis produces ______.
   - **a.** cells with the diploid chromosome number
   - **b.** cells with identical chromosomes
   - **c.** sex cells
   - **d.** a zygote

USING LAB SKILLS

10. In Activity 4-2 on page 94, you made a model of DNA using four bases. Design an alphabet with only four letters. How many words can you make using the four letters? The same letter may be used more than once. Using this exercise, what can you *infer* about the number of possible ways genes can combine?
11. Using the parts of the DNA model from Activity 4-2 and information in the MINI-Lab on page 90 about RNA, make a model showing how a strand of RNA is made from DNA.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

12. What is the difference between genes and chromosomes?
13. What are the differences between offspring formed by sexual reproduction and asexual reproduction?
14. What do spindle fibers do during mitosis and meiosis?
15. In what cells do mitosis and meiosis take place?
16. Why is more known about harmful mutations than beneficial ones?

APPLY

17. If one strand of DNA had bases ordered ATCCGTC, what would be the bases of its other strand?
18. A strand of RNA matching the DNA strand ATCCGTC would have what base sequence?
19. A mutation takes place in a human skin cell. Will this mutation be passed on to the person's offspring? Explain your answer.
20. What processes in mitosis provide both new cells with identical DNA?
21. How could a zygote end up with an extra chromosome?

MORE SKILL BUILDERS

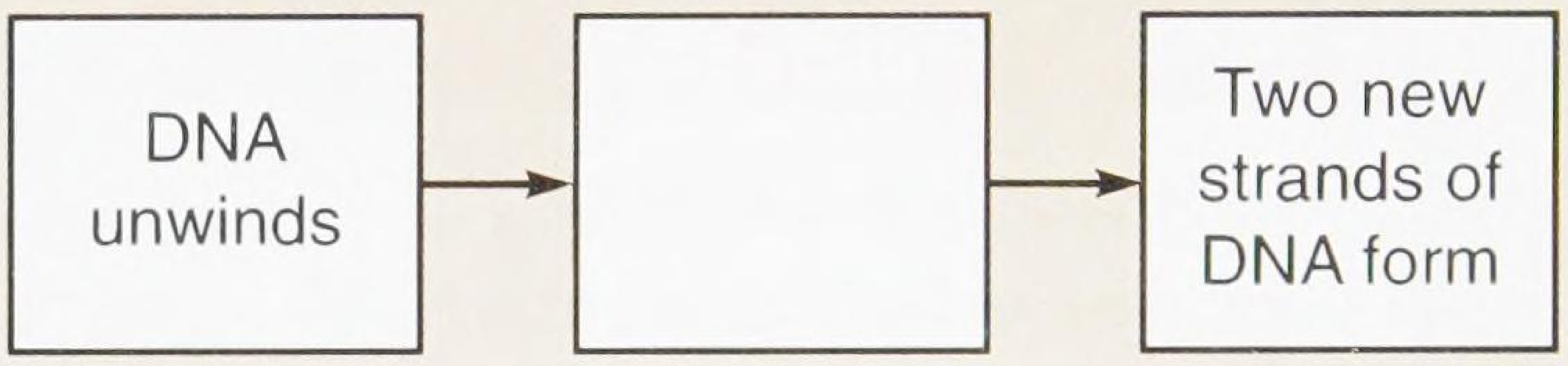
If you need help, refer to the Skill Handbook.

1. **Making and Using Tables:** Compare and contrast DNA and RNA in a table.

Nucleic acid	DNA	RNA
Number of stands	Use a separate sheet of paper to complete your table.	
Type of sugar		
Letter names of bases		
Where found?		

2. **Hypothesizing:** Make a hypothesis about the effect of an incorrect mitotic division on the new cells produced.

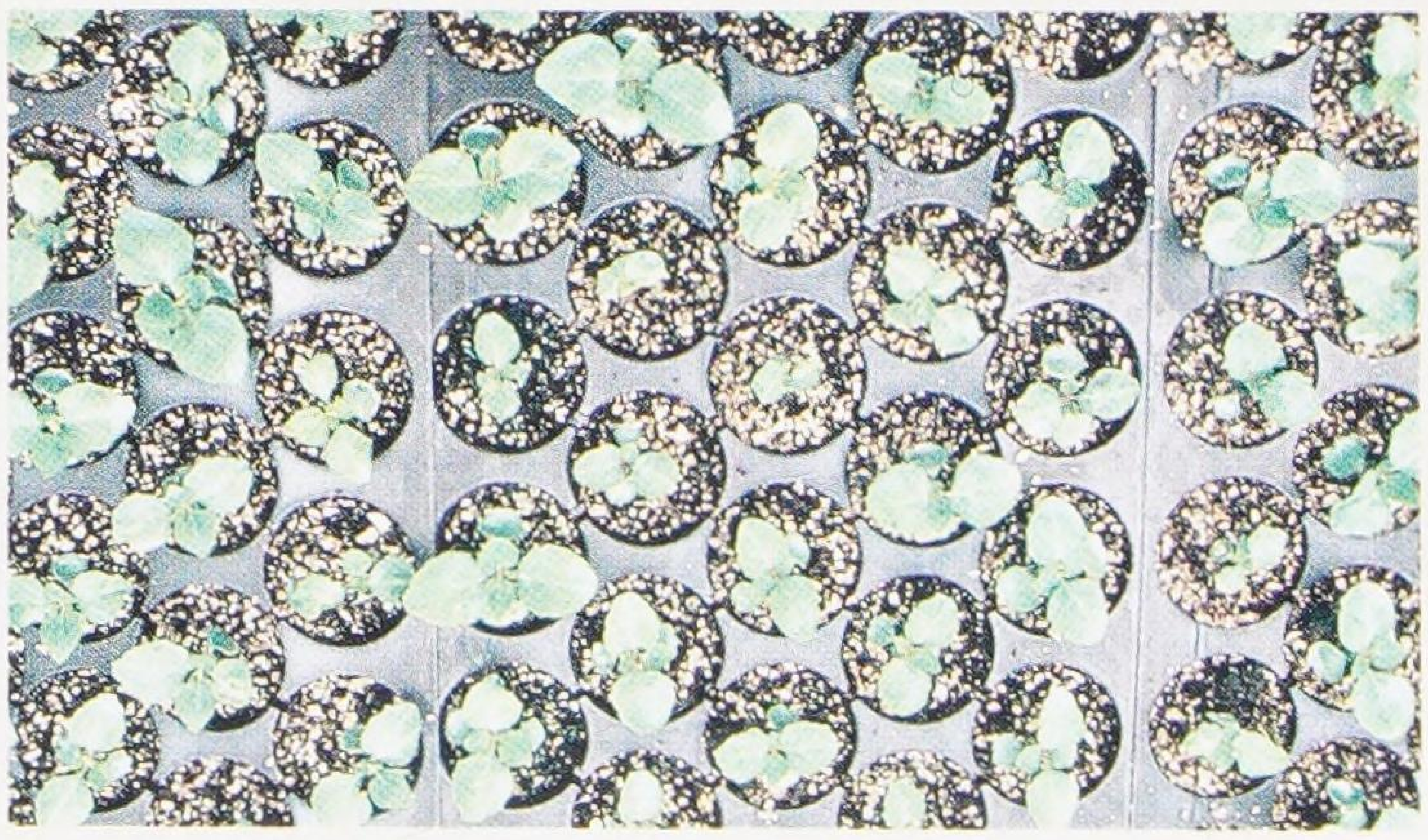
3. **Comparing and Contrasting:** In a table, compare and contrast mitosis and meiosis as to: number of divisions, numbers of cells produced, numbers of chromosomes in parent cells and in sex cells.
4. **Concept Mapping:** Complete the events chain concept map of DNA synthesis.



5. **Sequencing:** Sequence the events that occur in sexual reproduction. Start with interphase in the parent cell and follow it through production of a sex cell by meiosis. End with the formation of the zygote. Tell whether the number of chromosomes present at each stage is haploid or diploid.

PROJECTS

1. Research the events involved in exploring DNA since it was first removed from a cell nucleus in 1869. Show your results on a time line.
2. Write a one-page paper about growth hormones called gibberellins and their use.

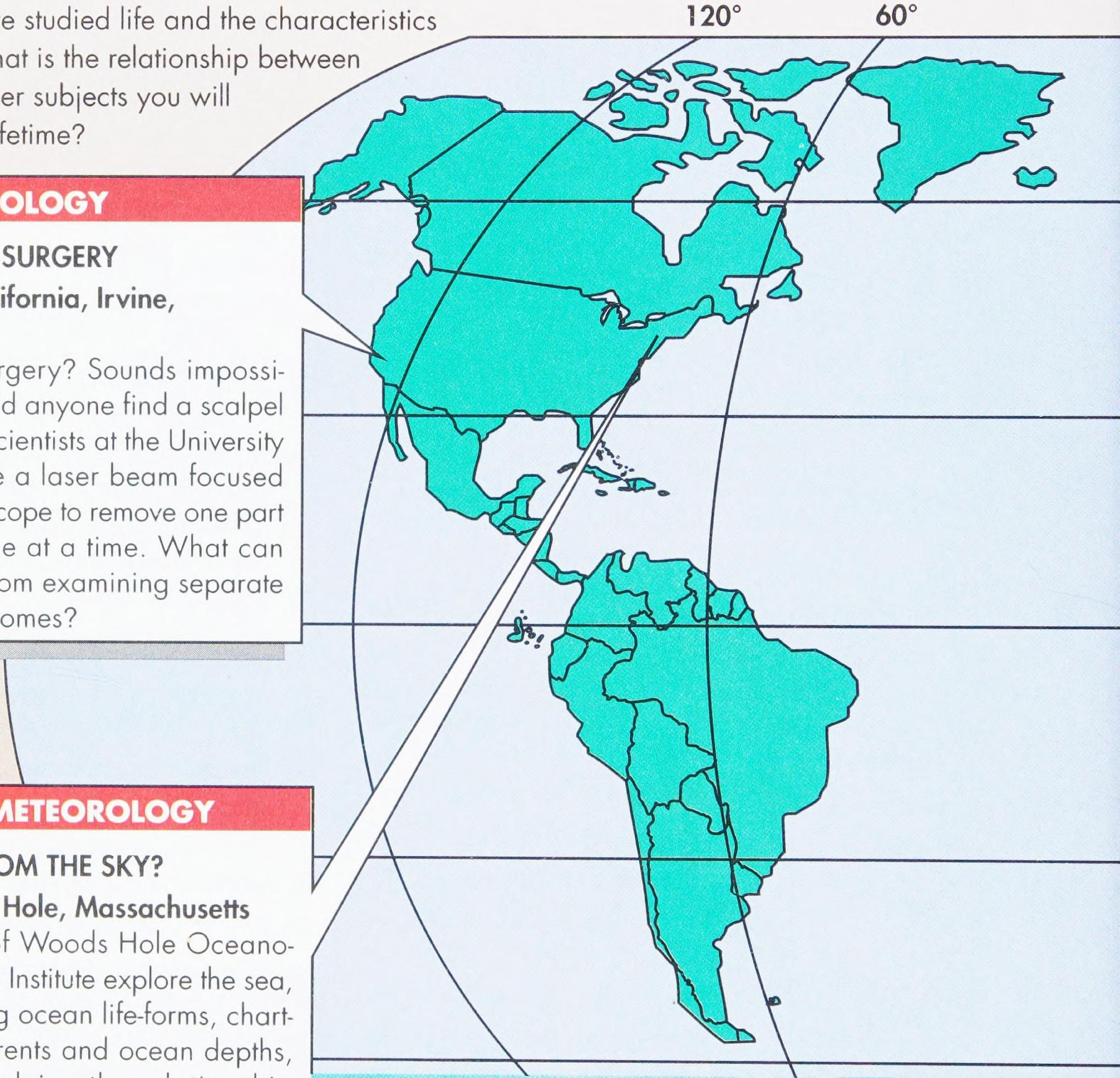


UNIT 1

GLOBAL CONNECTIONS

Life

In this unit, you have studied life and the characteristics of living things. What is the relationship between life science and other subjects you will encounter in your lifetime?



BIOLOGY

CHROMOSOME SURGERY

University of California, Irvine, California

Chromosome surgery? Sounds impossible! Where would anyone find a scalpel small enough? Scientists at the University of California use a laser beam focused through a microscope to remove one part of a chromosome at a time. What can scientists learn from examining separate parts of chromosomes?

METEOROLOGY

LIFE FROM THE SKY?

Woods Hole, Massachusetts

Ships of Woods Hole Oceanographic Institute explore the sea, studying ocean life-forms, charting currents and ocean depths, and studying the relationship between the ocean and rainfall. Why is rainfall important to living organisms?

HISTORY

LIVING OR DEAD?

Florence, Italy

An Italian physician, Francesco Redi, cast doubt on the theory of "spontaneous generation" in the 1600s. He exposed covered and uncovered jars of meat to flies. Redi found that flies would not grow on the covered meat. What are some other ways of testing spontaneous generation?

OCEANOGRAPHY

LIFE IN THE TRUK LAGOON

Carolina Islands, Western Pacific

A sunken Japanese fleet, left in the Pacific from World War II, provides a unique laboratory for new life. Because researchers know the date on which the ships were sunk, they can measure the change in marine life on the wrecks. What might scientists learn from the marine life at this site?

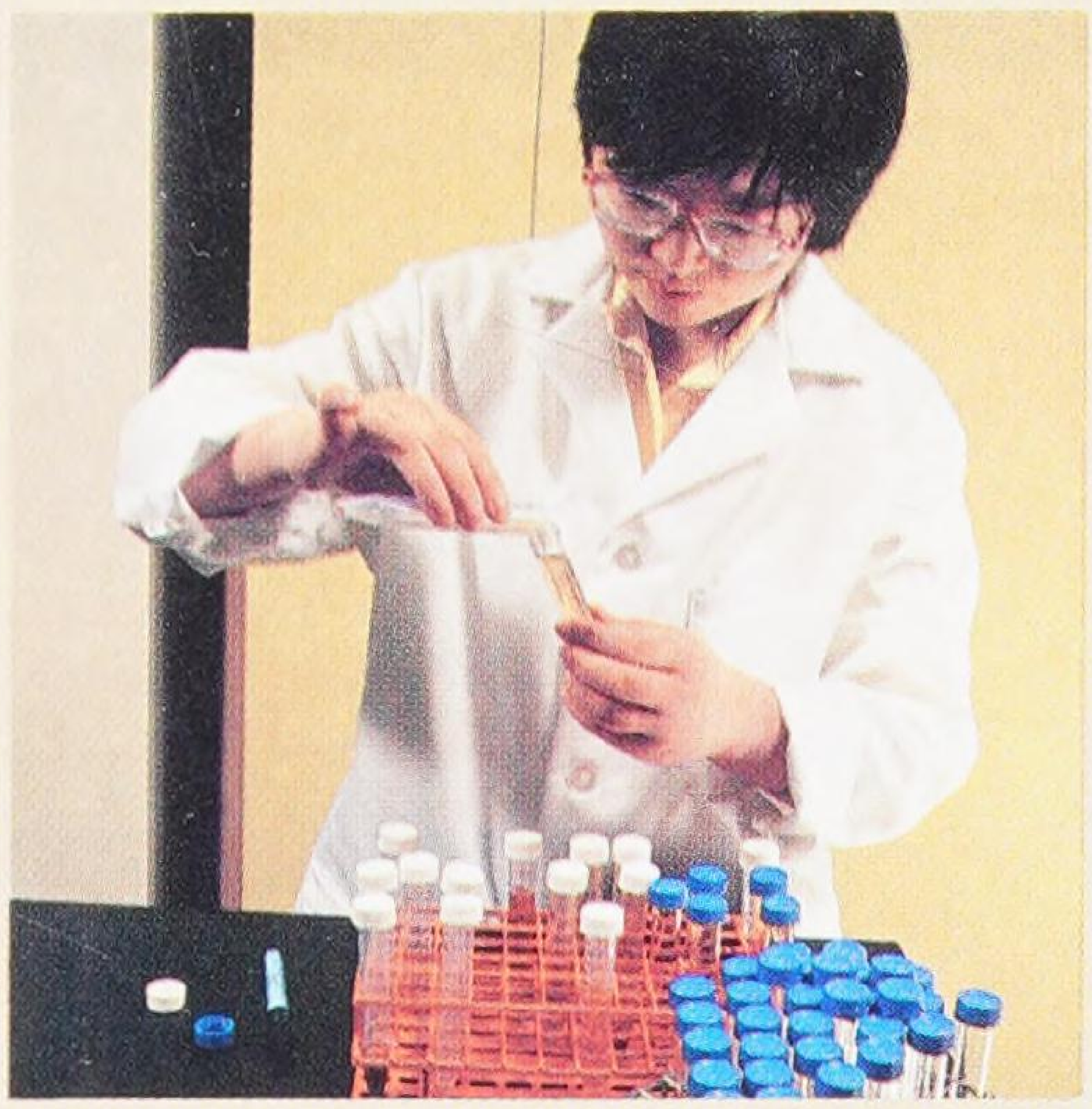
ASTRONOMY

LIFE IN OUTER SPACE?

Southern Australia

Most scientists think that life began through the synthesis of organic compounds from ammonia, methane, and water. These same compounds have been discovered in space. A meteorite was found to contain amino acids. If life were to exist on other planets, what kind of conditions would it need?

CAREERS



LABORATORY TECHNICIAN

A *laboratory technician* provides daily care for laboratory experiments. Education requirements vary. Most laboratory technicians must have three years of work-related experience. Some laboratories may require one or two years of college-level courses in basic biology and English.

Other laboratory technicians assist scientists in setting up, maintaining, and monitoring specialized equipment for research projects in a university or government laboratory. For example, certain pieces of equipment such as electron microscopes and ultracentrifuges require specialized care. These technicians are usually trained on the job and by the equipment manufacturer. Most technician jobs require a high school diploma and mechanical aptitude. Some may require technical college training.

For Additional Information

Clinical Laboratory Technology, 818 Olive St. Suite 918, St. Louis, MO 63101

BIOLOGY TEACHER

A *biology teacher* is a science educator who works in schools helping students learn about living things.

Biology teachers teach about living things through lectures, demonstrations, and most importantly, having students involved in activities. At the middle/junior high school levels, the biology teacher and students may work in a laboratory doing experiments.

A bachelor's degree in biology is usually required by state departments of education to become certified as a biology teacher. Many teachers continue their professional development and obtain a master's degree. Often biology teachers take summer courses to experience field science and new teaching techniques.

For Additional Information

National Association of
Biology Teachers, 11250
Roger Bacon Dr. #19,
Reston, Virginia 22090.

UNIT READINGS

- ▶ Asimov, Isaac. *How Did We Find Out About the Beginning of Life?* Houston: Walker Publishing Co., 1982.
- ▶ "The Year in Science." *Discover,* January 1991, pp. 22-51.

Essays

by Sir Francis Bacon

Sir Francis Bacon wrote this essay in 1605 to illustrate the problems early scholars had developing scientific methods.

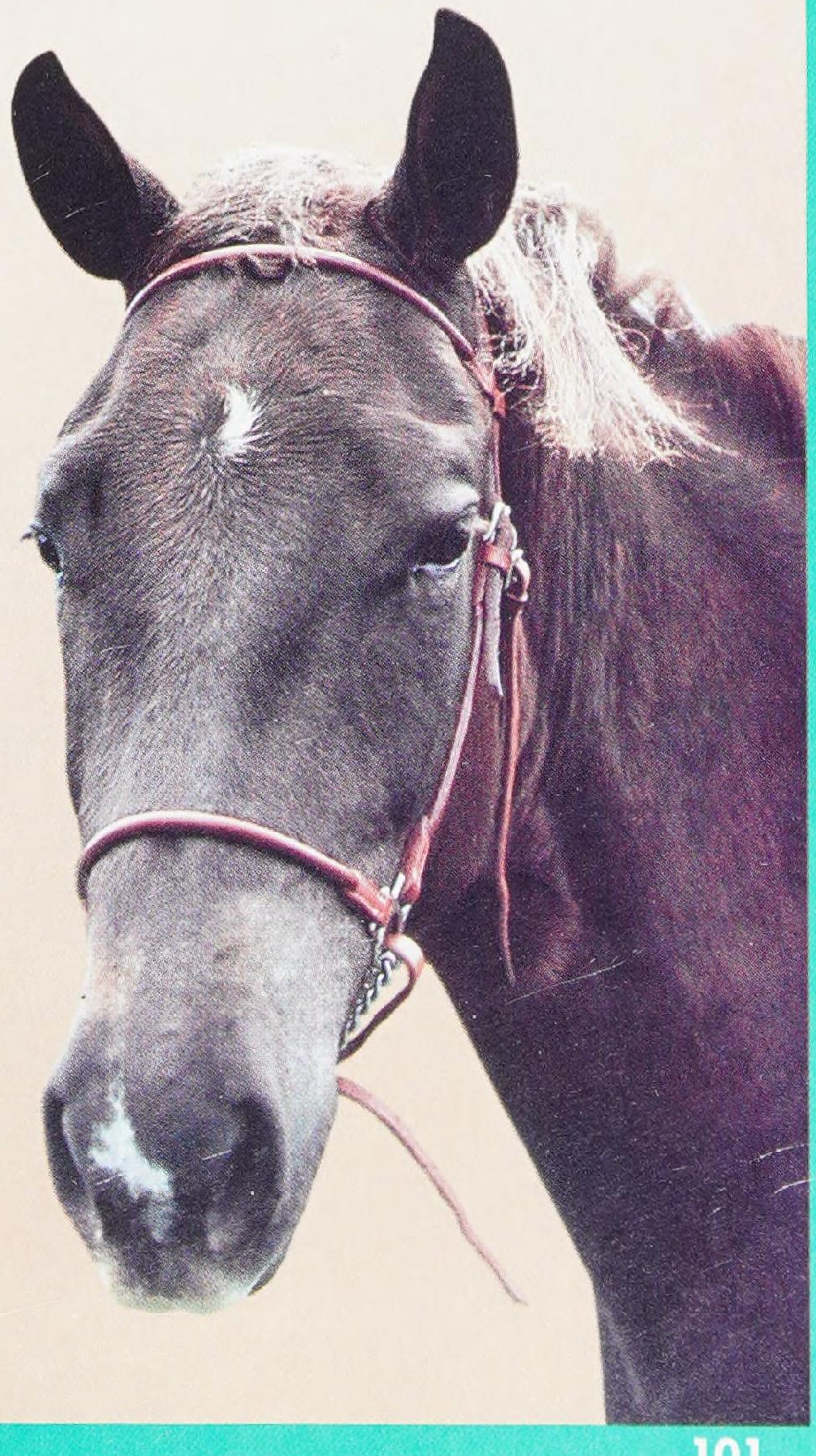
In the year of our Lord 1432, there arose a grievous quarrel among the brethren over the number of teeth in the mouth of a horse. For 13 days the disputation raged without ceasing. All the ancient books and chronicles were fetched out, and wonderful and ponderous erudition, such as was never before heard of in this region, was made manifest.

At the beginning of the 14th day, a youthful friar of goodly bearing asked his learned superiors for permission to add a word, and straightway, to the wonderment of the disputants, whose deep wisdom he sore vexed, he beseeched them to unbend in a manner coarse and unheard-of, and to look in the open mouth of a horse and find the answer to their questionings. At this, their dignity being grievously hurt, they waxed exceedingly wroth; and, joining in the mighty uproar, they flew upon him and smote him hip and thigh, and cast him out forthwith. For, said they, surely Satan hath tempted this bold neophyte to declare unholy and unheard-of ways of finding truth contrary to all the teachings of the fathers.

After many days more of grievous strife the dove of peace sat on the assembly, and they as one man, declaring the problem to be an everlasting mystery because of a grievous dearth of historical and theological evidence thereof, so ordered the same writ down."

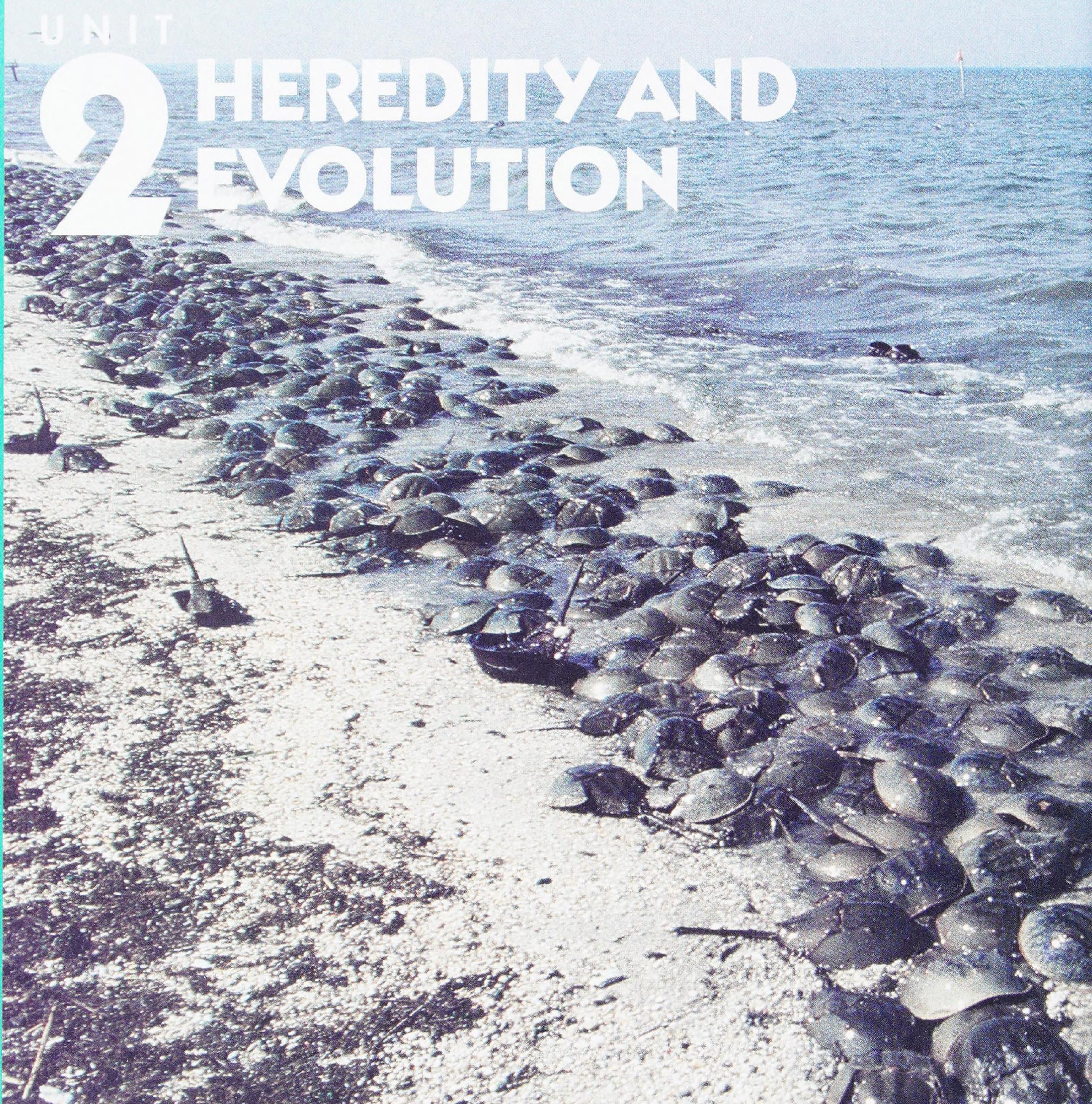
In Your Own Words

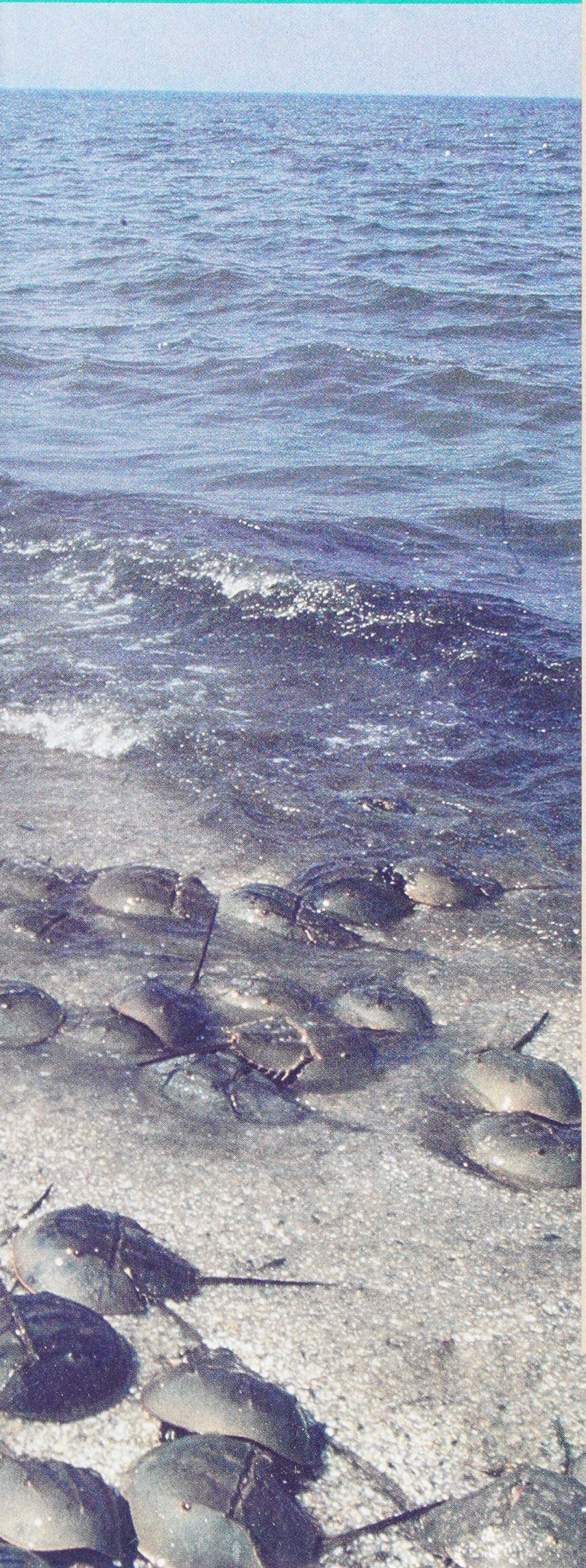
▶ Write a report explaining what part of the scientific method the "youthful friar" wanted his superiors to use. Explain how this problem might be approached by researchers today.



UNIT

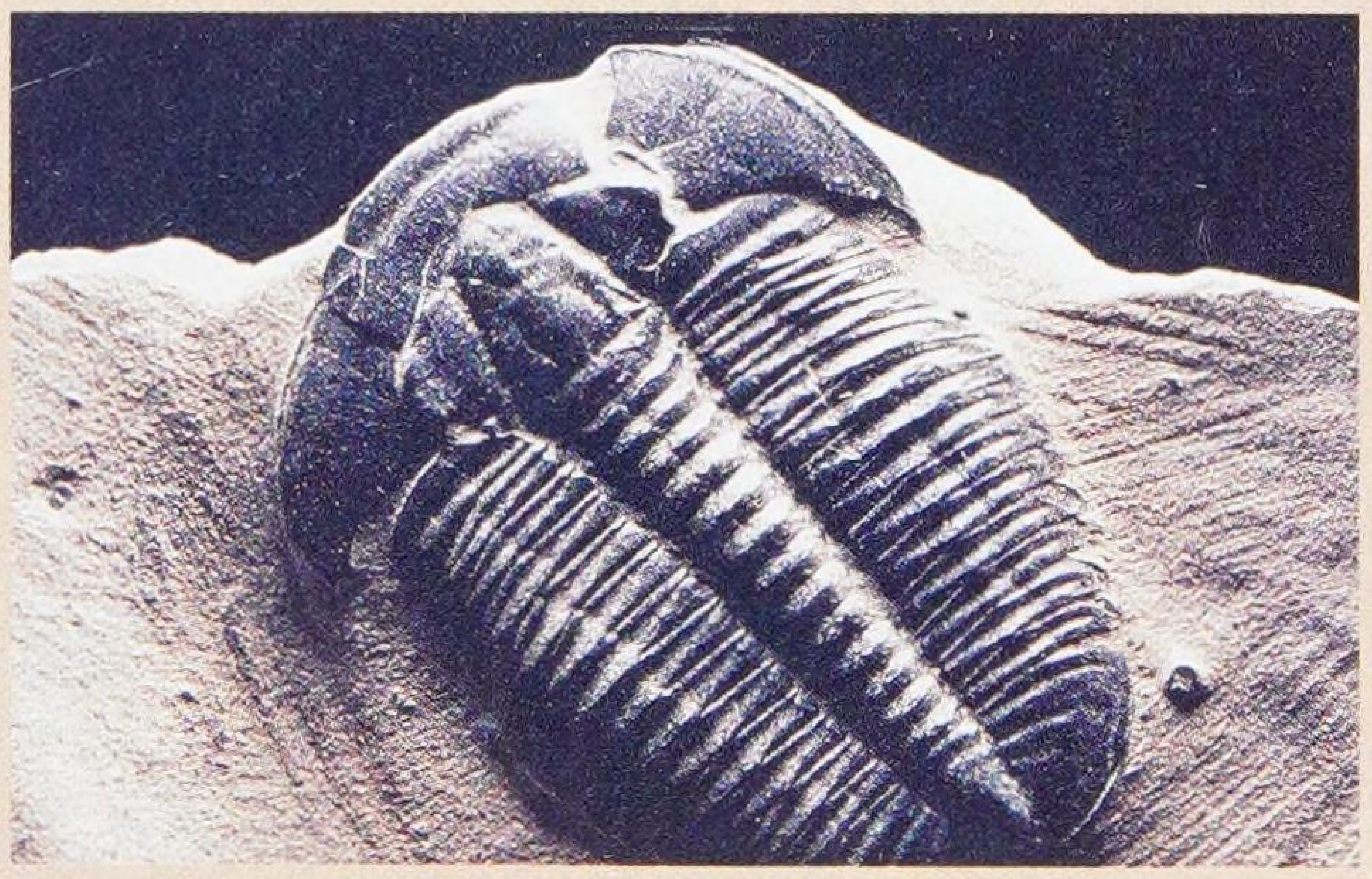
2 HEREDITY AND EVOLUTION





What's Happening Here?

What do cockroaches, crocodiles, and horseshoe crabs have in common? None of them has changed much since their first appearance on Earth. The horseshoe crabs on this beach are often called living fossils. In many ways they still resemble their trilobite ancestor shown in the small picture. What does this tell you about their ability to adapt? Nearly 99 percent of all species that have ever lived are now extinct, yet the horseshoe crab remains unchanged. Is it just luck? Is there some evolutionary principle at work here? In this unit, you'll learn more about heredity and evolution.

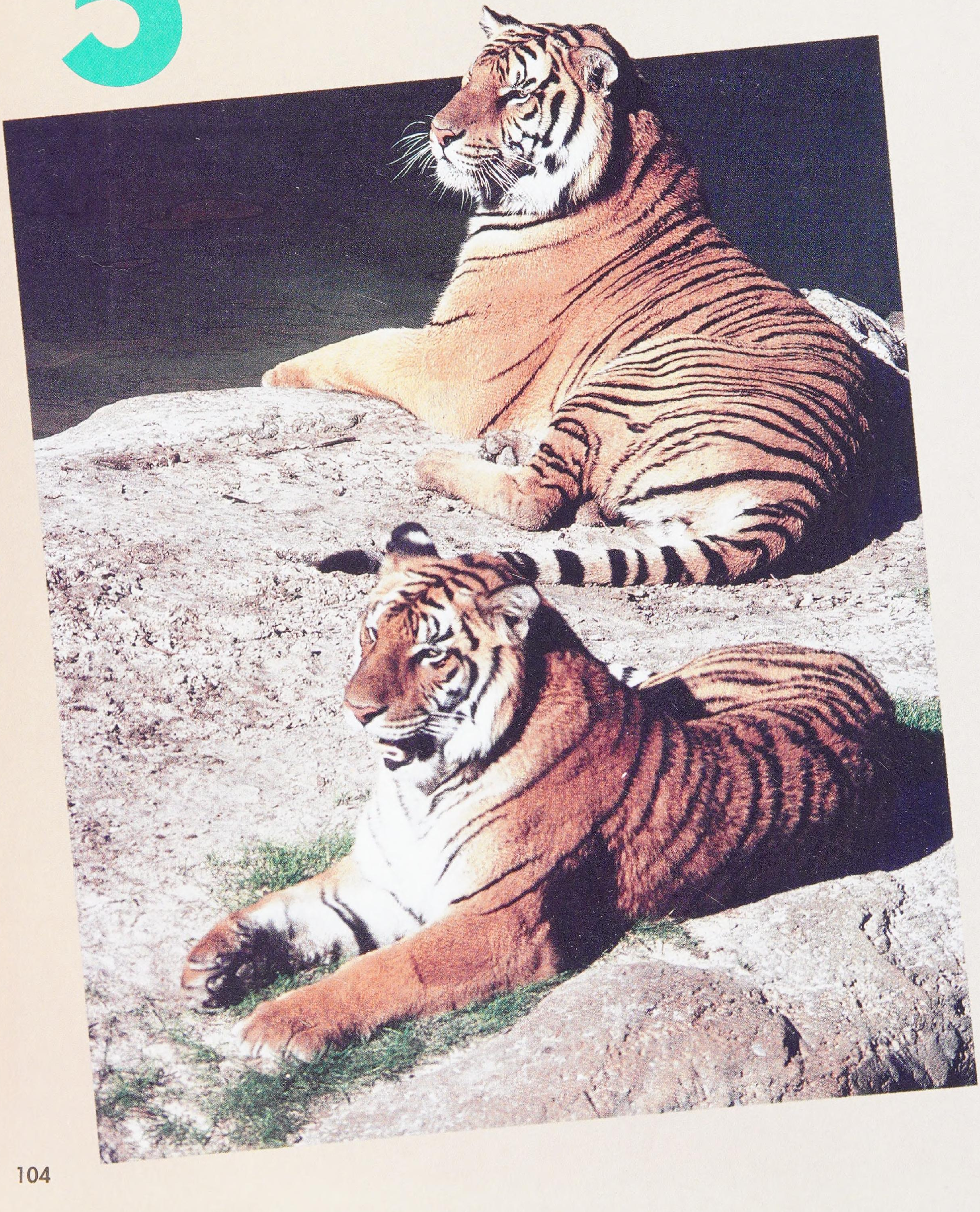


UNIT CONTENTS

Chapter 5 **Heredity**
Chapter 6 **Evolution**
Chapter 7 **Classification of Living Things**

CHAPTER

5 Heredity

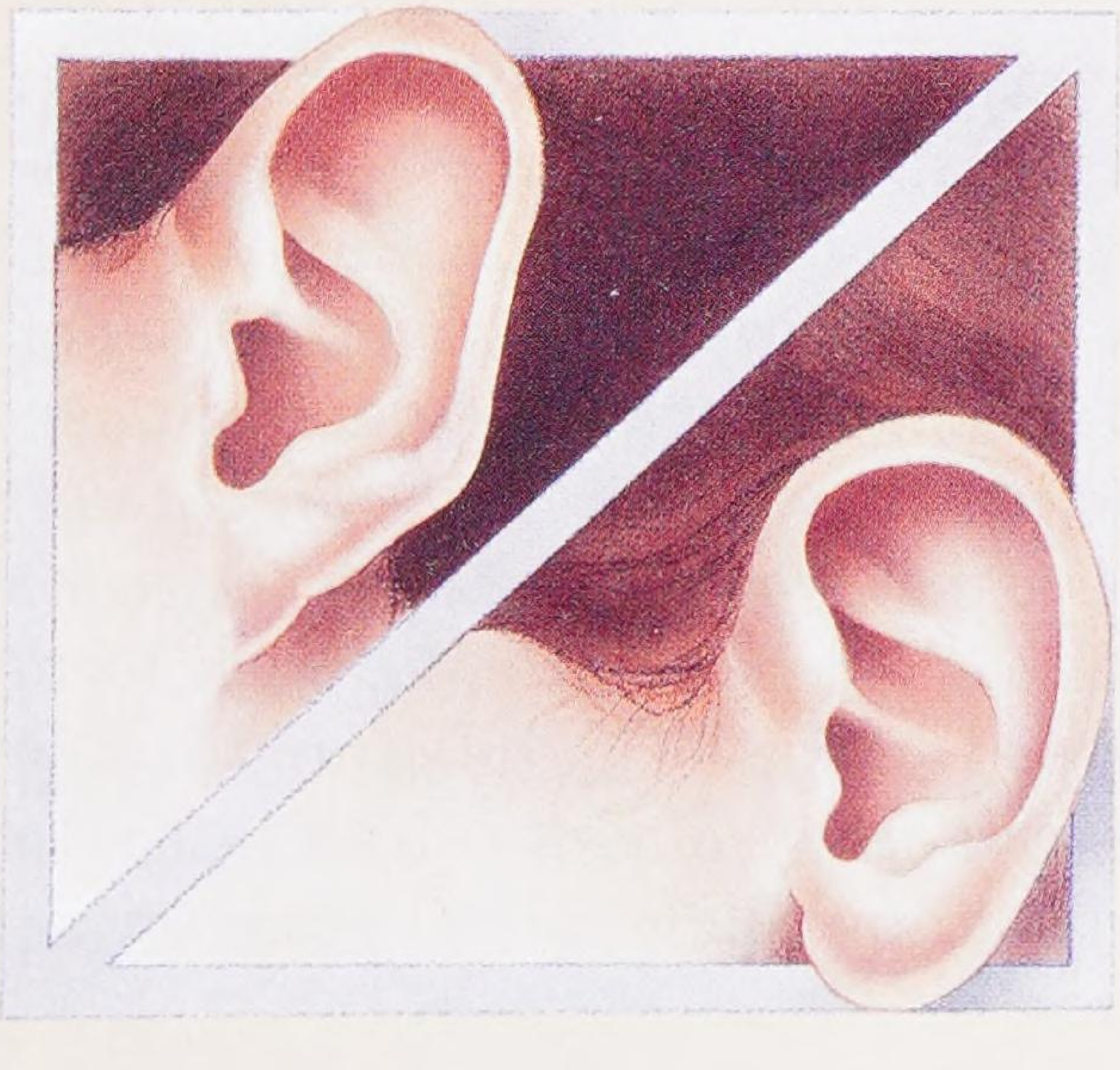


The tigers in the photo to the left have so many traits in common that they look almost identical. Most traits found in organisms have at least two different forms, such as free and attached earlobes in humans. How are these and other traits distributed among your classmates?

FIND OUT!

Do this activity to find out about the types of earlobes in your class.

Some people have earlobes that are attached, whereas others have earlobes that swing free. Count the number of your classmates who have attached earlobes. How many have free earlobes? *Record* the number of people in your class who have each type. What does your data tell you about the earlobe trait in your class? Do you have enough data to say which form of earlobe is more common in the human population?



Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 5-1 What Is Genetics?
- What Have You Inherited?
- The Father of Genetics
- Mendel's Experiments
- Using a Punnett Square

Section 5-2 Genetics Since Mendel
- Incomplete Dominance
- Multiple Alleles
- Multiple Genes

Section 5-3 Human Genetics
- Genes and Health
- Sex Determination
- Sex-linked Disorders
- Why Is Genetics Important?

Section 5-4 Science and Society The Human Genome
- Tracking Human Genes

Previewing Science Skills

- In the **Skill Builders,** you will observe and infer, compare and contrast, and use a concept map.
- In the **Activities,** you will experiment, hypothesize, and collect and analyze data.
- In the **MINI-Labs,** you will observe, collect and analyze data.

What's next?

Now that you have seen that a single human trait can have more than one form, learn about some of the ways in which these traits are inherited, and learn about the importance of genetics in your life.

5-1 What Is Genetics?

New Science Words

heredity
alleles
genetics
dominant
recessive
Punnett square
genotype
homozygous
heterozygous
phenotype

Objectives

- Explain how traits are inherited and explain Mendel's role in the history of genetics.
- Use a Punnett square to predict the results of crosses.
- Explain the difference between genotype and phenotype.

What Have You Inherited?

What's the first thing you think about when you hear the word *inheritance?* Money? A new home? People inherit all sorts of things. It might be a set of dishes or a set of tools. Of course, a lot of people will never inherit things like this. But there is a type of inheritance that all living things receive. For you, this inheritance is in the nucleus of each cell of your body in the form of sets of genes.

For centuries, people have been interested in why one generation looks like another. A new baby may look much like one of its parents. It may be the shape of its nose or its earlobes. In either case, a trait is being noticed. Every organism is a collection of traits, all inherited from its parents. **Heredity** (huh RED ut ee) is the passing of traits from parent to offspring. What controls these traits? As you will learn, traits are controlled by genes.

MINI-Lab

What are some common traits?

Survey 25 students in your class or school for the presence of freckles, dimples, tongue rolling, bent little fingers, and cleft chin. *Record* your results *in a table* **in your Journal.** Describe all the variations you notice.

What is an allele?

In 1933, an American scientist, Thomas Hunt Morgan, stated that genes are found on chromosomes. Genes, as you learned in Chapter 4, are made up of DNA. They control all the traits that show up in an organism. When pairs of chromosomes separate into sex cells during meiosis, pairs of genes also separate from one another. As a result, each sex cell winds up with one form of a gene for each trait that an organism shows. If the trait is for earlobes, then the gene in one sex cell may control one form of the trait, such as attached earlobes. The gene for earlobes in the other sex cell may control the other form of the trait, such as free earlobes. The different forms a gene may have for a trait are its **alleles** (uh LEELZ). In life science, the study of how alleles affect generations of offspring is **genetics.**

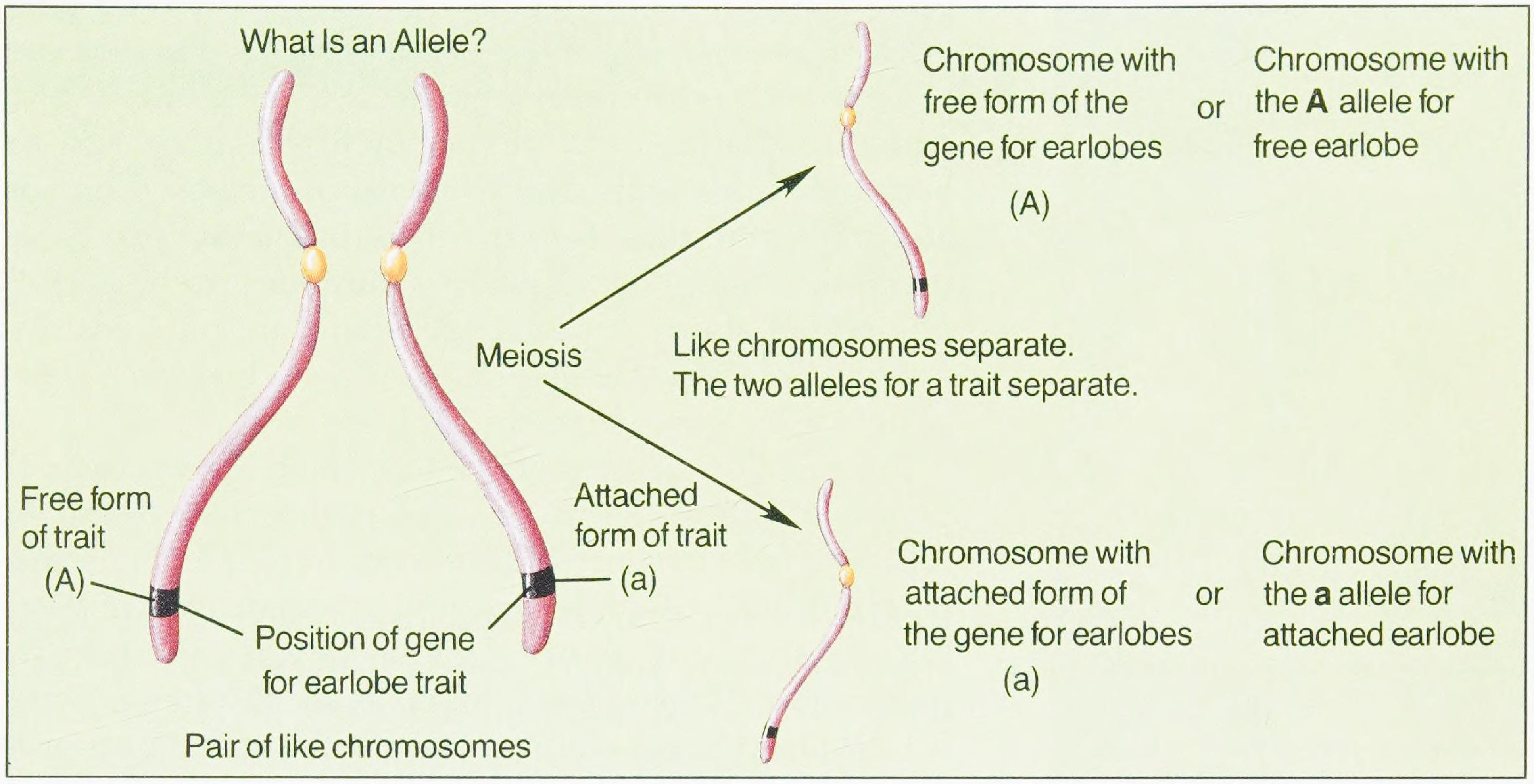

What Is an Allele?
Free form of trait
(A)
Attached form of trait
(a)
Position of gene for earlobe trait
Pair of like chromosomes
Meiosis
Like chromosomes separate.
The two alleles for a trait separate.
Chromosome with free form of the gene for earlobes
(A)
or
Chromosome with the **A** allele for free earlobe
Chromosome with attached form of the gene for earlobes
(a)
or
Chromosome with the **a** allele for attached earlobe

Figure 5-1. An allele is one form of a gene. Alleles separate into sex cells during meiosis.

The Father of Genetics

The first thorough scientific study of how traits pass from one generation to the next was done by a monk, Gregor Mendel. Mendel lived in the 1800s in a section of Eastern Europe that was part of Czechoslovakia. His father taught him about plants in the family's small orchard. Although everyone expected him to become a farmer, he became a priest. He studied science and math and eventually worked many years as a substitute teacher. While teaching, Mendel took over a garden plot at the monastery. There he experimented with plants. His observations of his father's orchard made him think that it was possible to predict the kinds of flowers and fruit a plant would produce. But something had to be known about the parents of the plant before a prediction could be made. Mendel made extremely careful use of scientific methods in his research. In 1866, after eight years of work on inheritance in plants, Mendel presented the results of his research to a group of scientists. Unfortunately, they didn't understand anything he was talking about. Mendel died in 1884, without knowing if his work would ever be understood.

In 1900, Mendel's work was rediscovered. By then, other scientists had come to the same conclusions that he had reached. Since then he has become known as the Father of Genetics.

Figure 5-2. Through experiments, Mendel discovered basic laws of inheritance.

Figure 5-3. Many people breed dogs for specific traits. The dog above is a sheepdog, originally bred because it could be trained to tend and drive sheep.

Mendel's Experiments

Mendel chose ordinary green peas, like the ones you've eaten for dinner, for his experiments. Peas are easy to breed for pure traits. You've heard of purebred horses and purebred dogs. An organism that always produces the same traits in its offspring is pure, or purebred. Tall plants that always produce tall plants are pure for the trait of tall height. Altogether, Mendel studied seven traits of peas, which are shown in Table 5-1.

In one of his first experiments, Mendel crossbred tall plants with short plants. He took pollen from the male reproductive structure of flowers of pure tall plants and placed it on the female reproductive structures of flowers of pure short plants. This process is called cross-pollination. The results of this cross are shown in Figure 5-4. Notice that tall plants crossed with short plants produce all tall plants. It seemed as if whatever had caused the plants to be short had disappeared.

Mendel called the tall height form that appeared the **dominant** factor, because it seemed to dominate or cover up the short height form. In this case, the tall height form was dominant. He called the form that seemed to disappear the **recessive** factor. But what had happened to the recessive form? He experimented to find out.

Mendel allowed the new tall plants to cross-pollinate. Then he collected the seeds from these tall plants and planted them. To his surprise, the plants that grew from these seeds were tall and short. The recessive form had reappeared. Mendel saw that for every three tall plants

Figure 5-4. A cross between pure tall plants and pure short plants (a) produces a generation of all tall plants (b). When the first generation tall plants are crossed with each other, a second generation is produced with three tall plants for every one short plant (c).

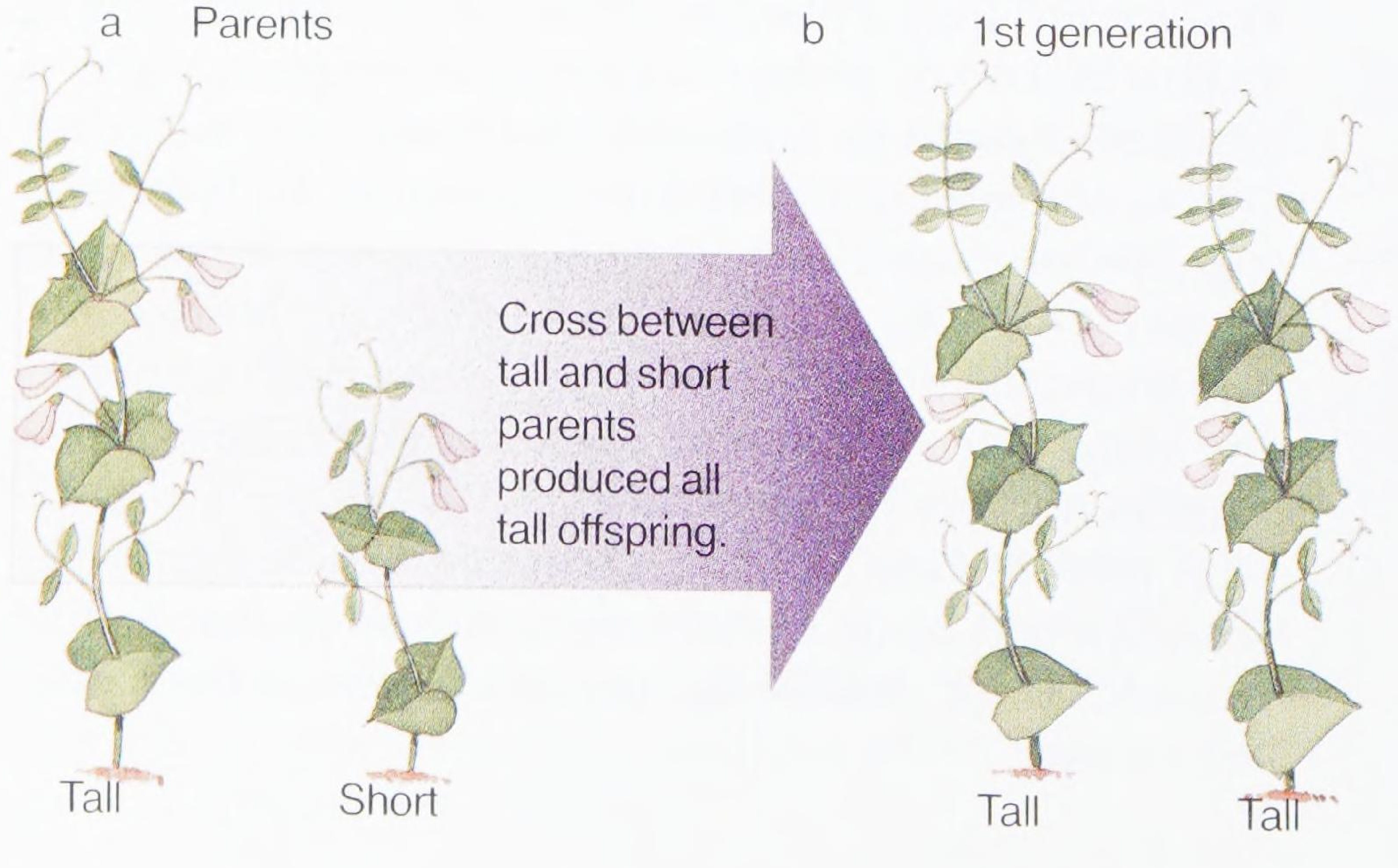
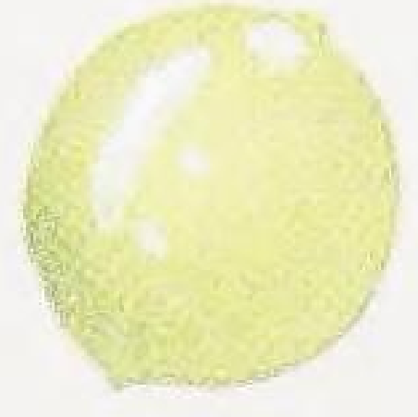
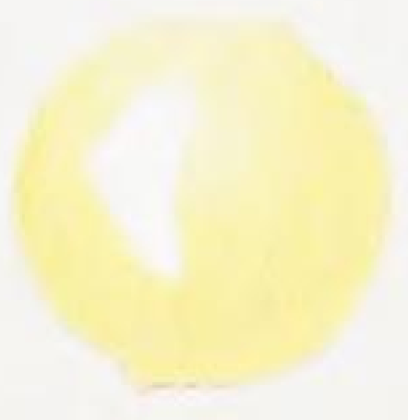
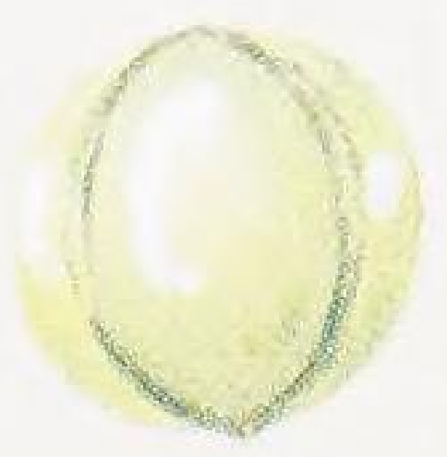
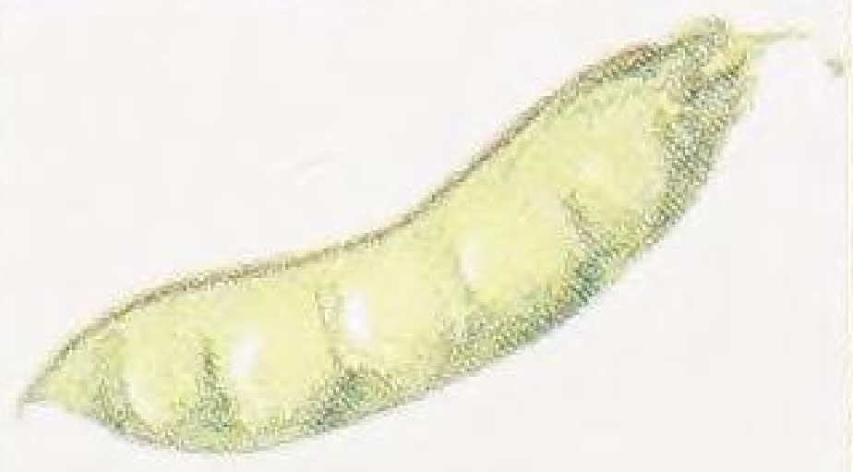
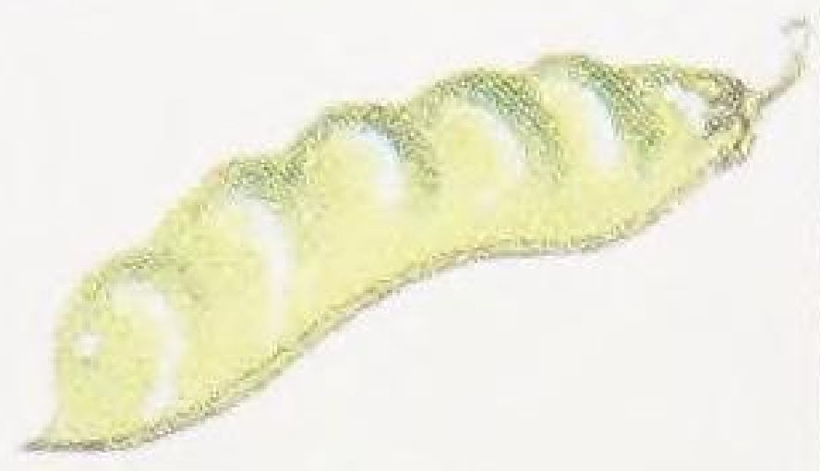
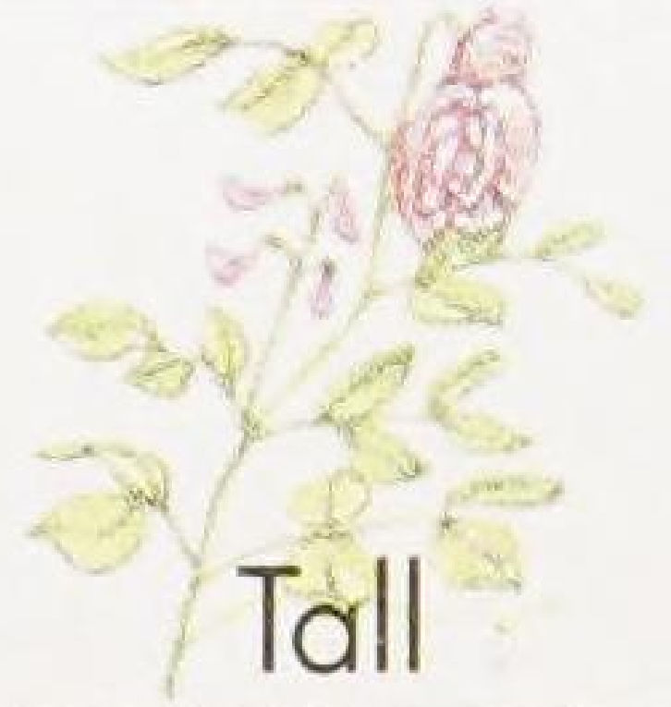
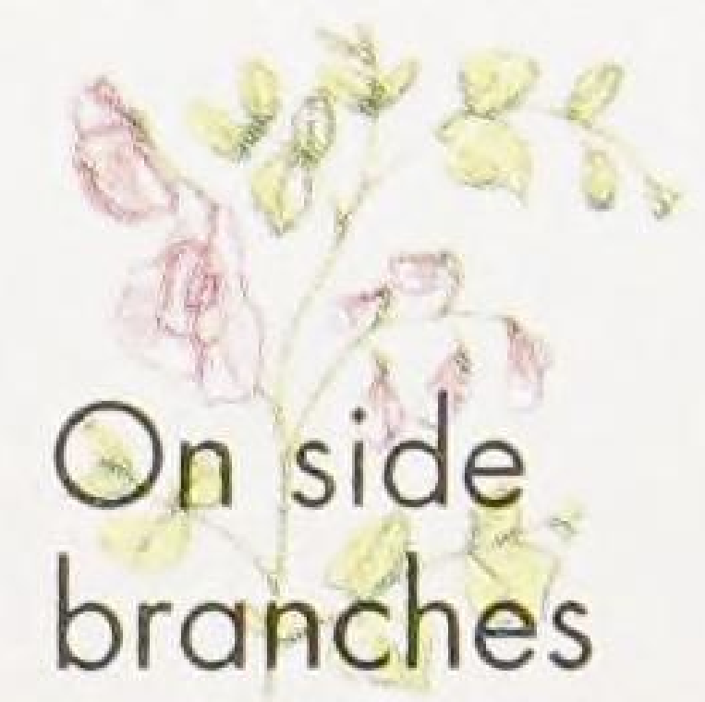
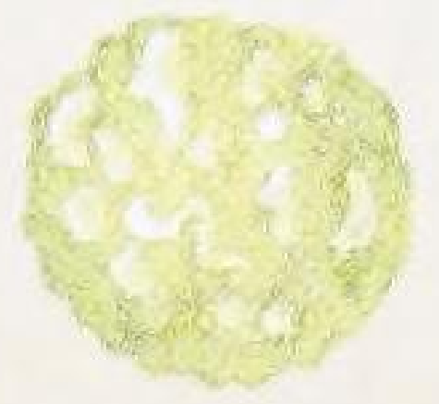
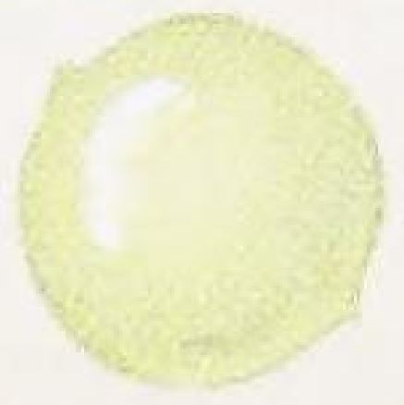
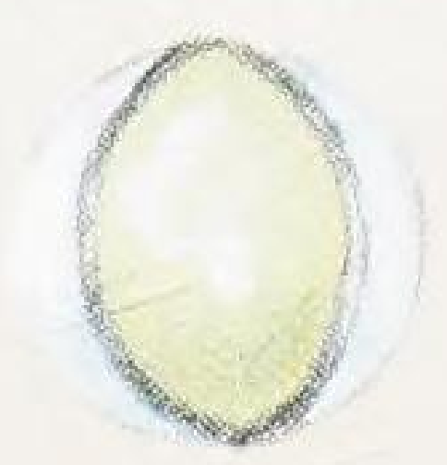
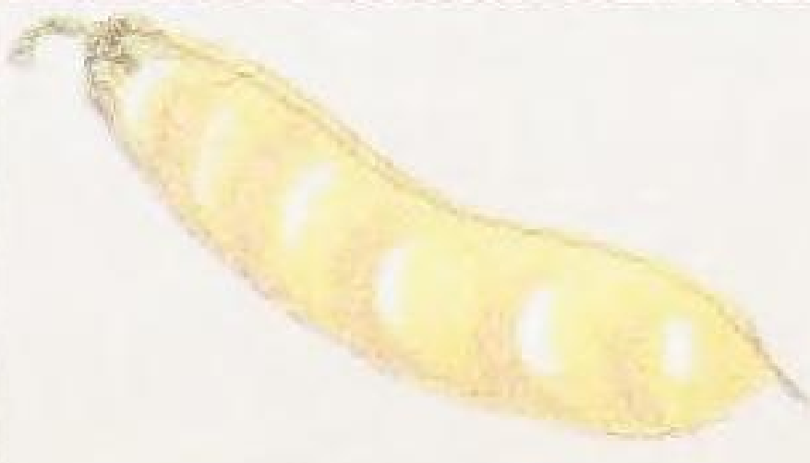
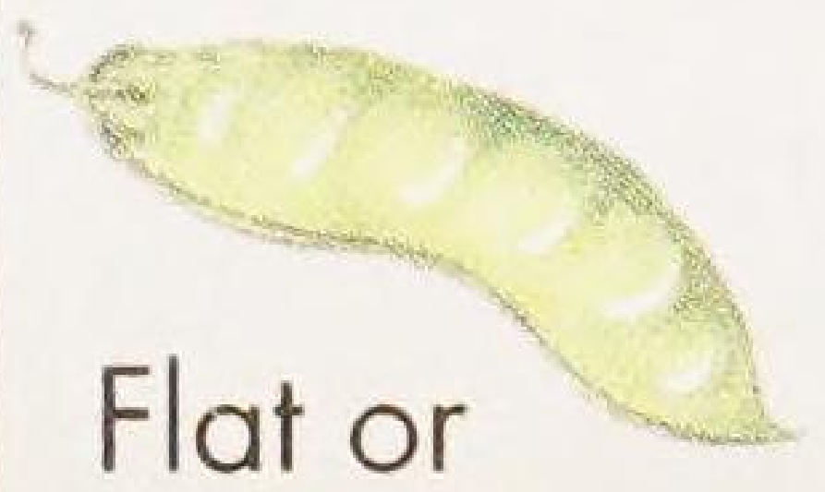
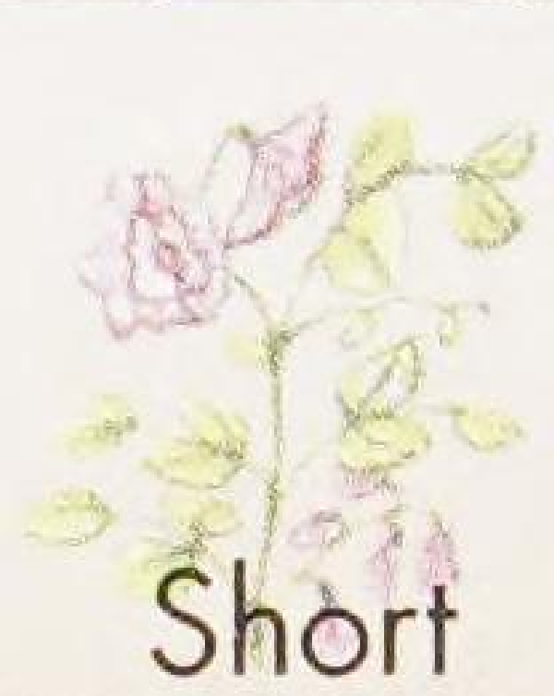
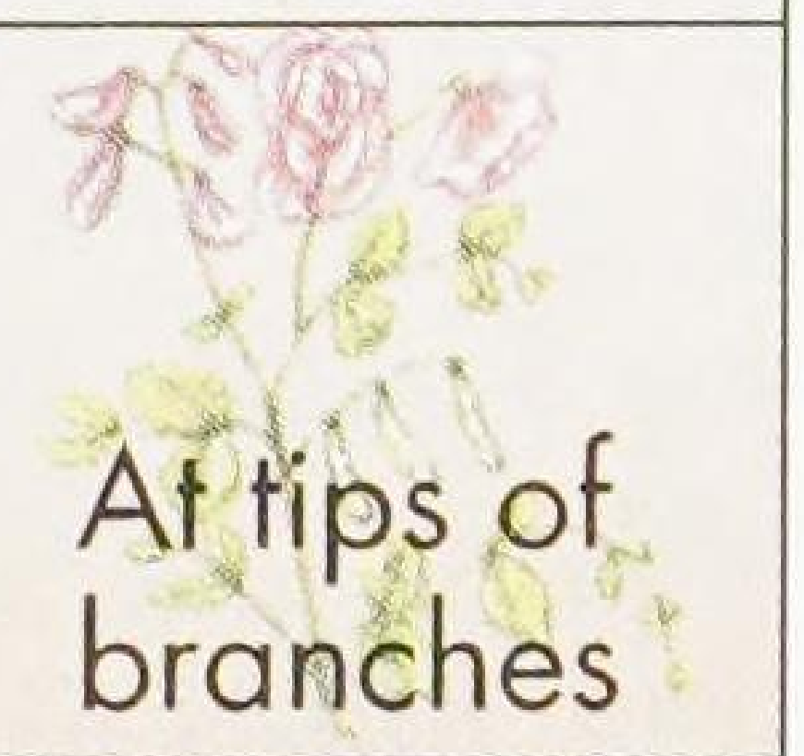

a
Parents
b
1st generation
Cross between tall and short parents produced all tall offspring.
Tall
Short
Tall
Tall

Table 5-1

TRAITS COMPARED BY MENDEL

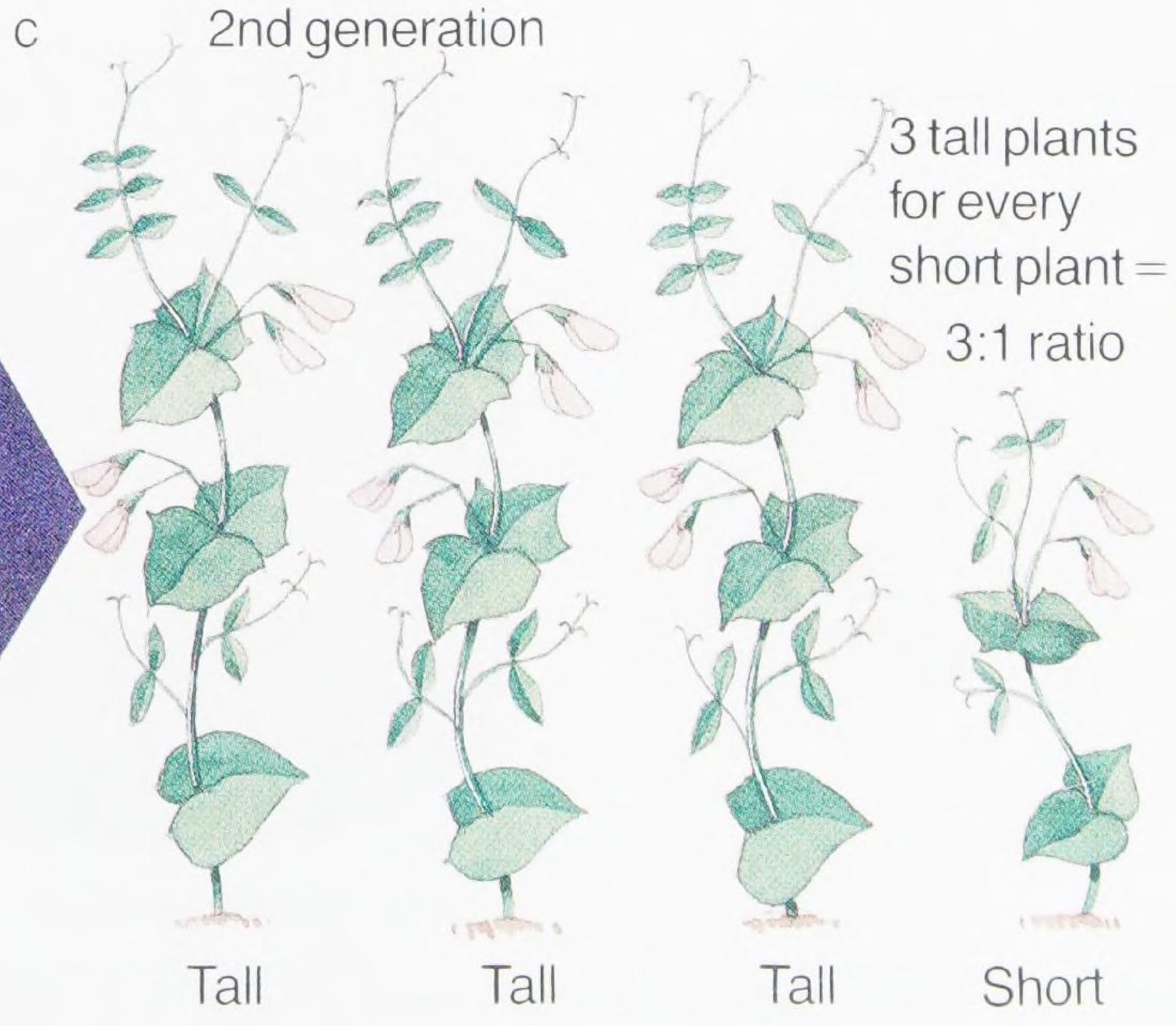
Shape of seeds	Color of seeds	Color of seed coats	Color of pods	Shape of pods	Plant height	Position of flowers
 Round	 Yellow	 Green	 Green	 Full	 Tall	 On side branches
 Wrinkled	 Green	 White	 Yellow	 Flat or Constricted	 Short	 At tips of branches

Dominant traits appear in top row of the table.

there was one short plant, or a 3:1 ratio. He saw this 3:1 ratio often enough that he knew he could predict his results when he started a test. He knew that the *probability* was great that he would get that same outcome each time.

Probability is a science that helps you determine the chance that something will take place. Suppose your cat comes running every time you open a can of cat food. If the cat acts this way every day for a year, then you can say that the probability of the cat acting that way every day for the next year is very great. As a matter of fact, the probability is 100 percent. You can predict it.

Mendel also dealt with probabilities. One of the things that made his predictions accurate was that he worked with large numbers. He counted every plant and thousands of seeds. Now, this may not sound like fun, but by doing so, Mendel increased his chances of having accurate results. Scientific research is based on accurate, repeatable results.


c
2nd generation
3 tall plants for every short plant = 3:1 ratio
Tall
Tall
Tall
Short

Tall offspring crossed with tall offspring produced tall and short offspring. The short trait reappeared.

Connect to...

Chemistry

If Mendel's pea plants produced plants with no chlorophyll, what is the probability of these plants surviving to produce flowers and seeds? Explain your answer.

Using a Punnett Square

A handy tool used to predict results in genetics is the **Punnett square.** It uses your knowledge of alleles. Dominant and recessive alleles are represented by letters. A capital letter (*T*) stands for a dominant allele. A small letter (*t*) stands for a recessive allele. The letters are a form of shorthand. They show the genetic make-up, or **genotype,** of an organism. Once you understand what the letters mean, you can tell a lot about the inheritance of a trait in an organism.

Every cell in your body has two alleles for every trait. An organism with two alleles for a trait that are exactly the same is called **homozygous** (ho muh ZI gus). This would be written as *TT* or *tt*. An organism that has two different alleles for a trait is called **heterozygous** (het uh roh ZI gus). This condition would be written *Tt*. The purebred pea plants that Mendel used were homozygous for tall, or *TT*, and homozygous for short, or *tt*. The hybrid plants he produced were all heterozygous, or *Tt*.

The physical trait that shows as a result of a particular genotype is its **phenotype** (FEE nuh tipe). Red is the phenotype for red flowering plants. Short is the phenotype for short plants. If you have brown hair, then the phenotype for your hair color is brown.

Science and MATH

Suppose Mendel's tall plants sell for $20 per dozen. The short ones sell for $10 per dozen. **In your Journal,** *calculate* how much money you would make if you sold all of 100 dozen offspring plants from a first generation cross.

Explain the difference between heterozygous and homozygous.

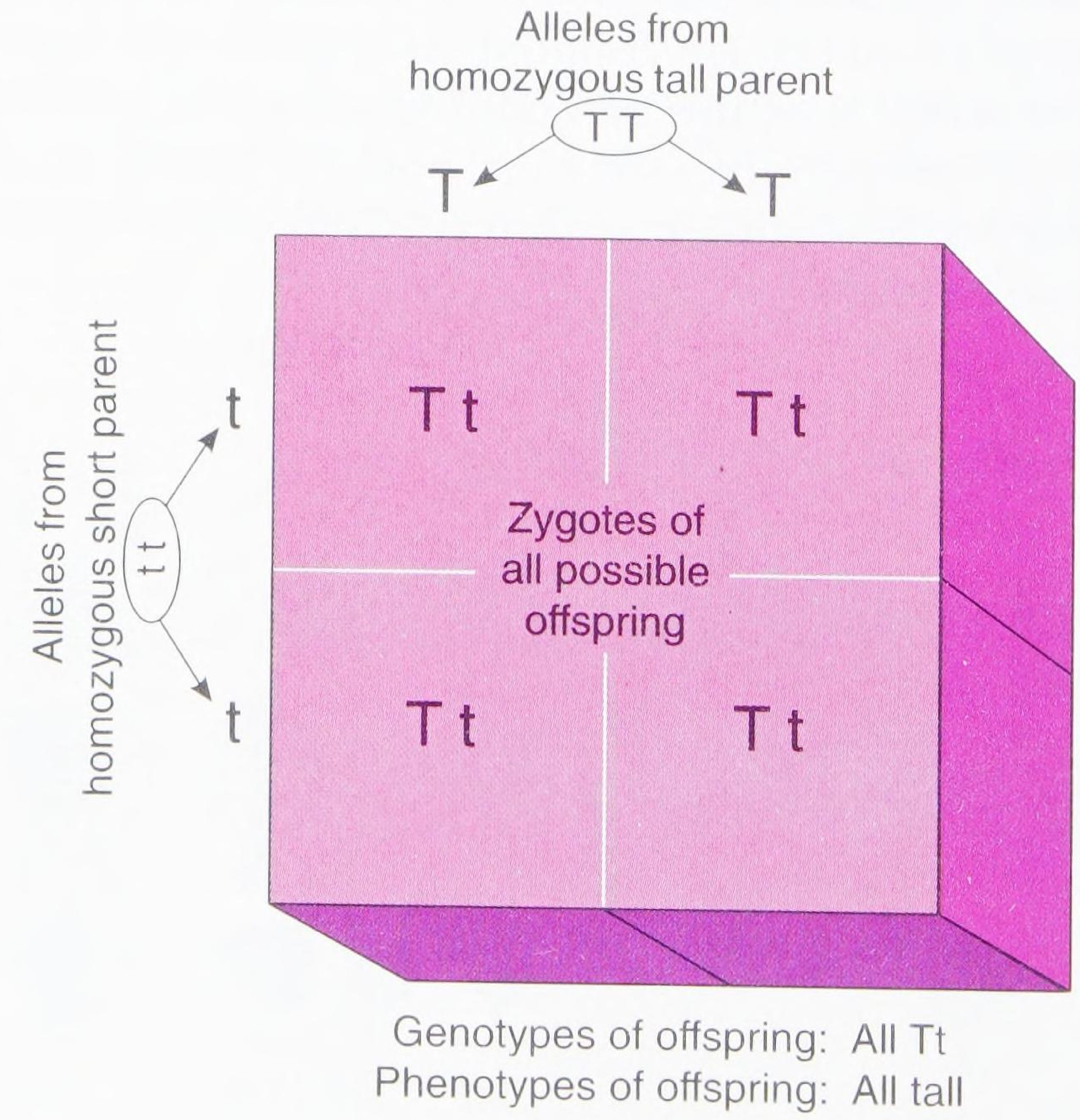

Alleles from homozygous tall parent
TT
T
T
Alleles from homozygous short parent
tt
t
t
Tt
Tt
Tt
Tt
Zygotes of all possible offspring
Genotypes of offspring: All Tt
Phenotypes of offspring: All tall

Figure 5-5. A Punnett square shows you all the ways in which alleles can combine. A Punnett square does *not* tell you how many offspring will be produced.

Look at the Punnett square in Figure 5-5. The letters representing the two alleles from one parent are written along the top of the square. Those of the second parent are placed along the side of the square. Each square in the middle is filled in much like a multiplication problem with one allele donated by each parent. The letters that you use to fill in each of the squares represent the genotypes of zygotes that the parents *could* produce.

The Punnett square in Figure 5-5 represents the first type of cross-pollination experiment by Mendel. You can see that each homozygous parent plant has two alleles for height. One parent is homozygous for tall (*TT*). The other parent is homozygous for short (*tt*). The alleles inside the squares are the genotypes of the possible offspring. All of them have the genotype *Tt*. They all have tall as a phenotype. Notice that you can't always figure out a genotype just by looking at the phenotype. The combination of *TT* or *Tt* both produce tall plants when *T* is dominant to *t*. Study the additional sample problems given below.

Figure 5-6. The color phenotype of this hibiscus flower is red.

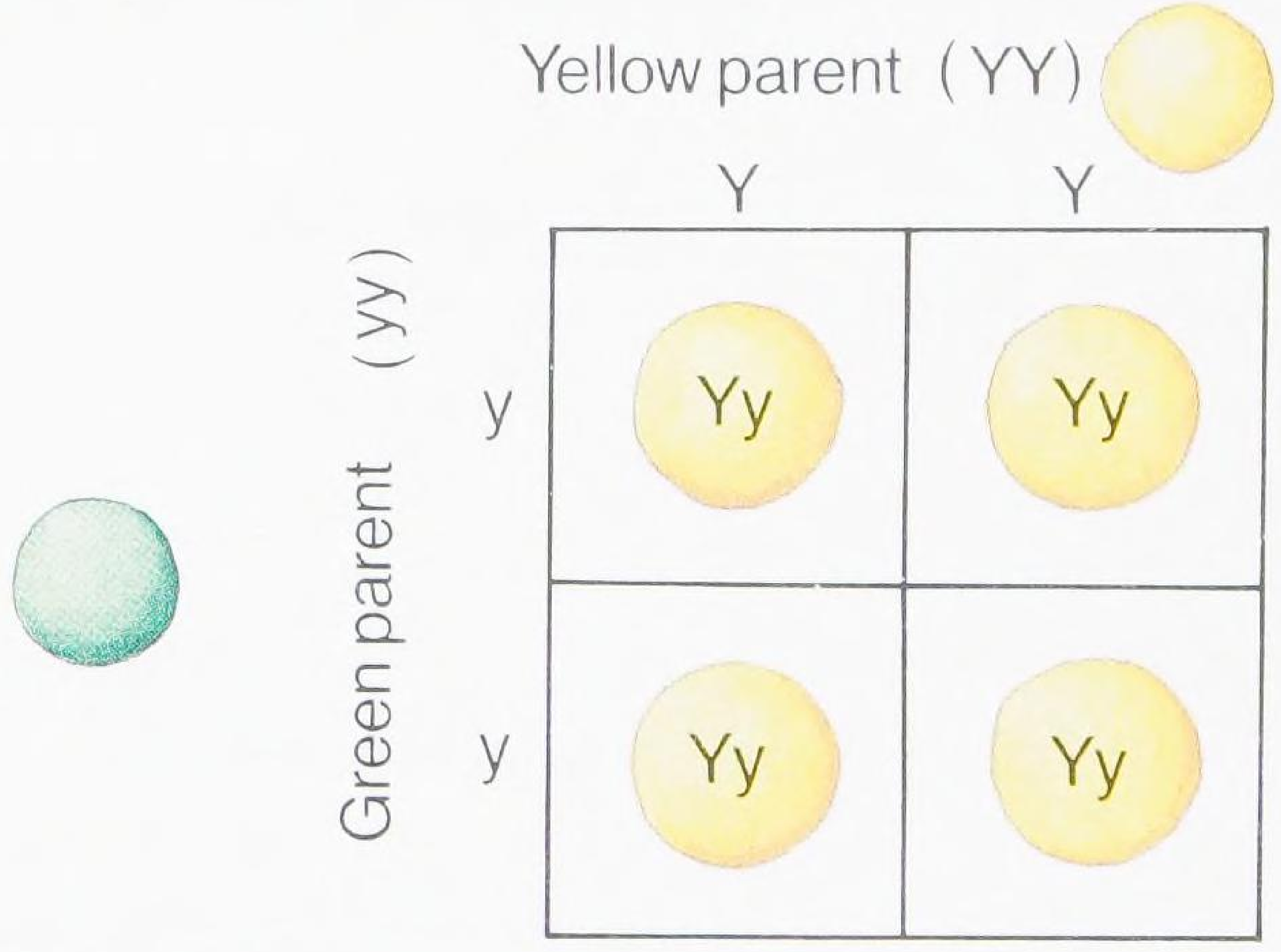
EXAMPLE PROBLEMS: Using Punnett Squares

Problem 1: Color in Peas

Yellow color in peas is dominant to green peas. A homozygous yellow pea plant is crossed with a homozygous green pea plant. What will the genotypes of all the possible offspring be?

Outcome:

Genotypes of all possible offspring: All Yy
Phenotypes of offspring: All yellow



Problem 2: Wing Length in Fruit Flies

In fruit flies, long wings (L) are dominant to short wings (l). Two heterozygous long-winged fruit flies (both Ll) are crossed. What are the possible genotypes of their offspring? What are the phenotypes?

Outcome:

Genotypes of all possible offspring: LL, Ll, and ll
Phenotypes of all possible offspring:
LL and Ll = long wings
ll = short wings

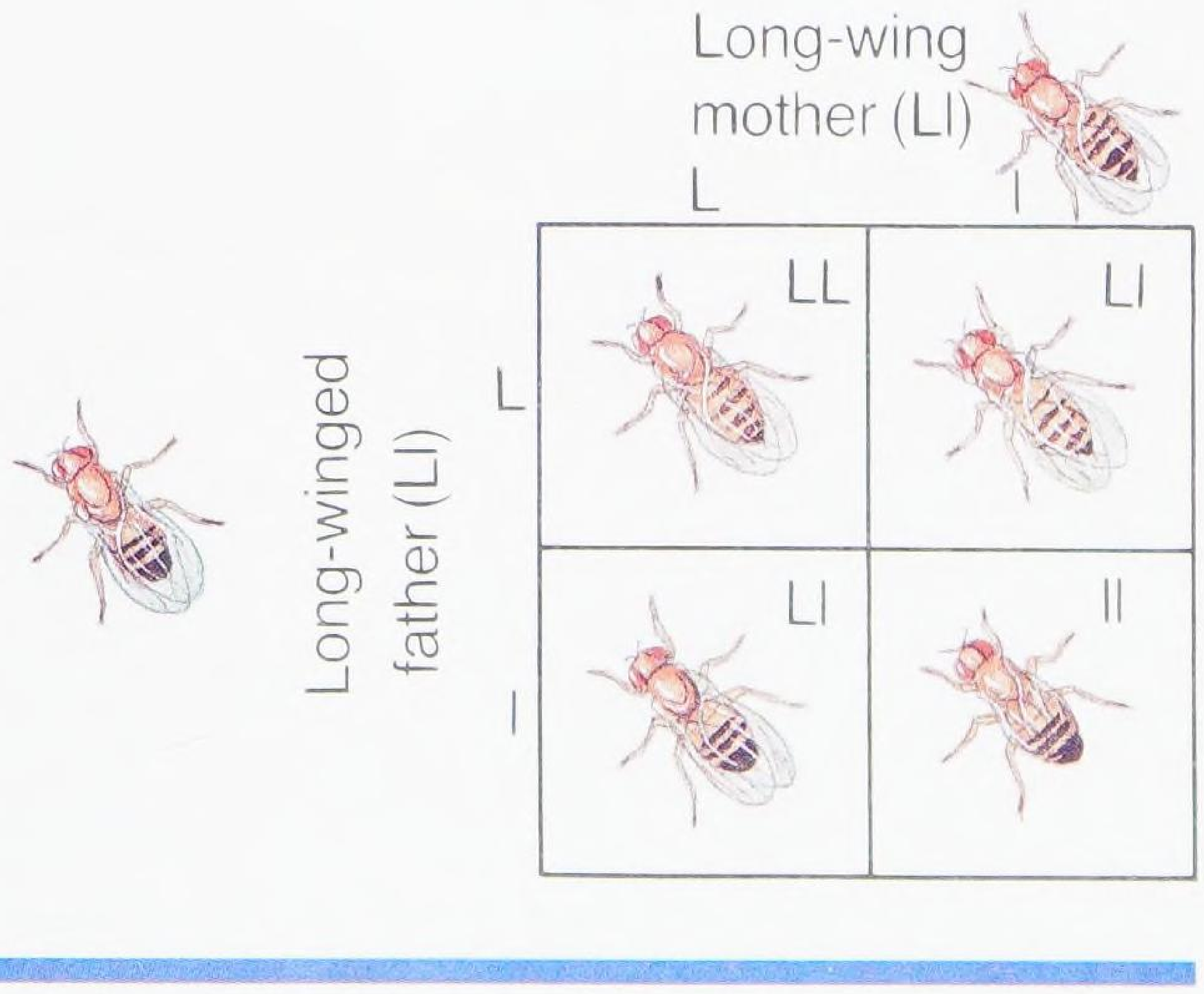


Table 5-2

MENDELIAN INHERITANCE

1. Traits are controlled by alleles on chromosomes.
2. An allele may be dominant or recessive in form.
3. When a pair of chromosomes separates during meiosis, the different alleles for a trait move into separate sex cells.

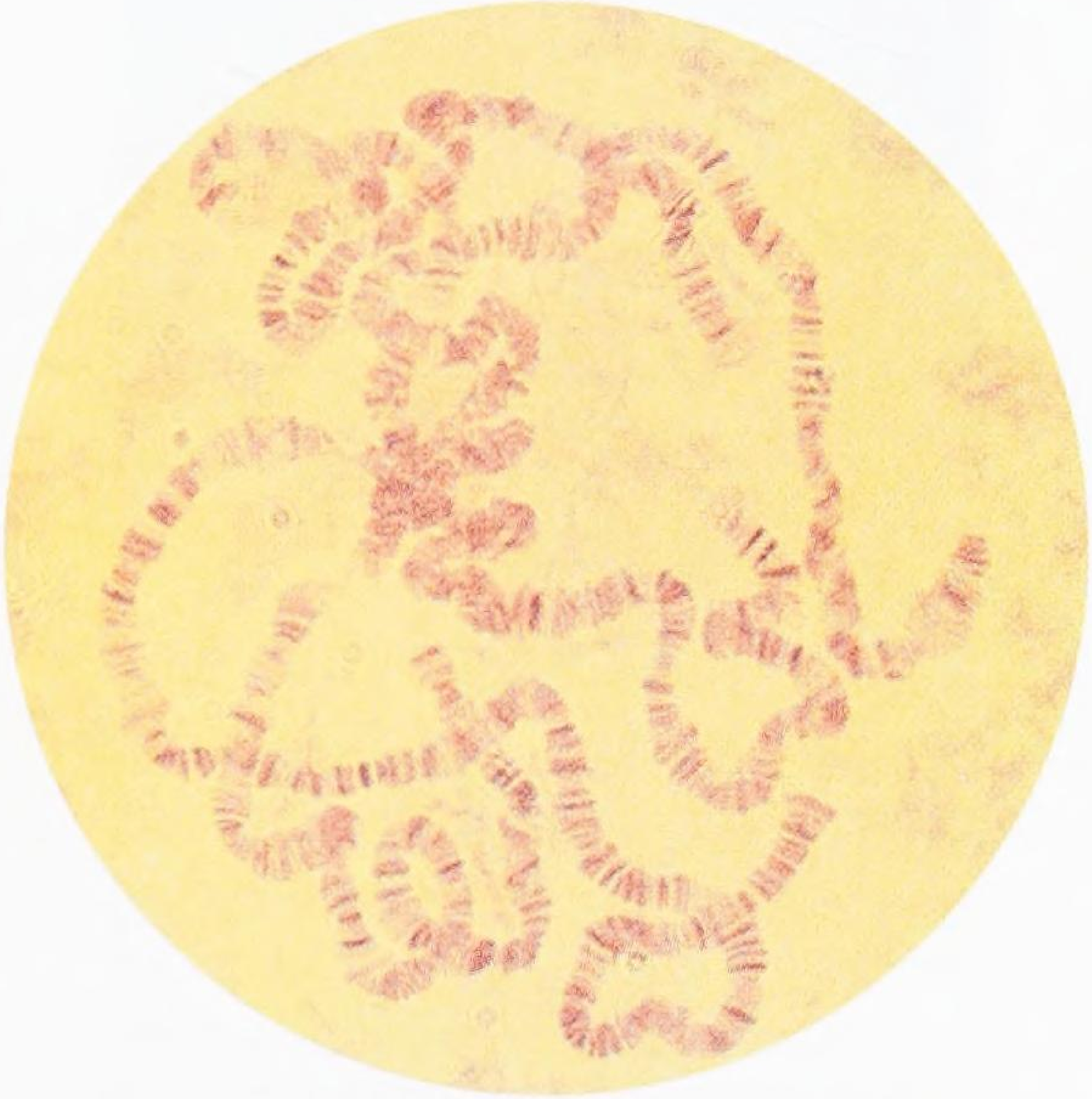


Figure 5-7. The markings on these chromosomes show where DNA is located.

Gregor Mendel didn't know anything about DNA, genes, or chromosomes. He did figure out that "factors" in the plants caused certain traits to appear. He also figured out that these factors separated when the plant reproduced. Mendel arrived at his conclusions by patient observation and careful analysis. His work is summed up briefly in Table 5-2.

SECTION REVIEW

1. How are alleles and traits related?
2. Differentiate between genotype and phenotype.
3. Explain Mendel's contribution to genetics.
4. **Apply:** Make a Punnett square showing a cross between two dogs. One dog is homozygous for black coat, and the other dog is homozygous for white coat. Black is dominant to white. Use *B* for the dominant allele and *b* for the recessive allele. What are the genotypes of the parents and the genotypes and phenotypes of the puppies?
5. **Connect to Earth Science:** Give an example of how probability is used in everyday life.

Skill Builder

☐ Observing and Inferring

Hairline shape is an inherited trait in humans. A widow's peak is a V-shaped hairline in the middle of the forehead. People lacking the trait have a straight hairline. The widow's peak allele is dominant and the straight hairline allele is homozygous recessive. From your study of Mendel's experiments, infer how parents with widow's peaks could have a child without the trait. If you need help, refer to Observing and Inferring in the **Skill Handbook** on page 682.

ACTIVITY 5-1

Expected and Observed Results

Problem: *How does chance affect combinations of genes?*

Materials

- 2 paper bags
- 100 red beans
- 100 white beans

Procedure

1. Place 50 red beans and 50 white beans into a paper bag. Place 50 red beans and 50 white beans into a second bag. Each bean represents an allele for flower color.
2. Label one of the bags "female" for the female parent. Label the other bag "male" for the male parent.
3. Without looking inside the bags, remove one bean from each bag. The two beans represent the alleles that combine when sperm and egg join.
4. Use a Punnett square to predict how many red/red, red/white, white/white combinations will be selected.
5. Make a table like the one shown with room for 100 data entries. Record the color combination of the beans each time you remove two beans. Then return them to their original bags and shake the bags.
6. Repeat Steps 5 and 6 *ninety-nine* times.
7. Count and record the total numbers of red/red, red/white, and white/white bean combinations in your data table.
8. Compile and record the class totals.

Data and Observations

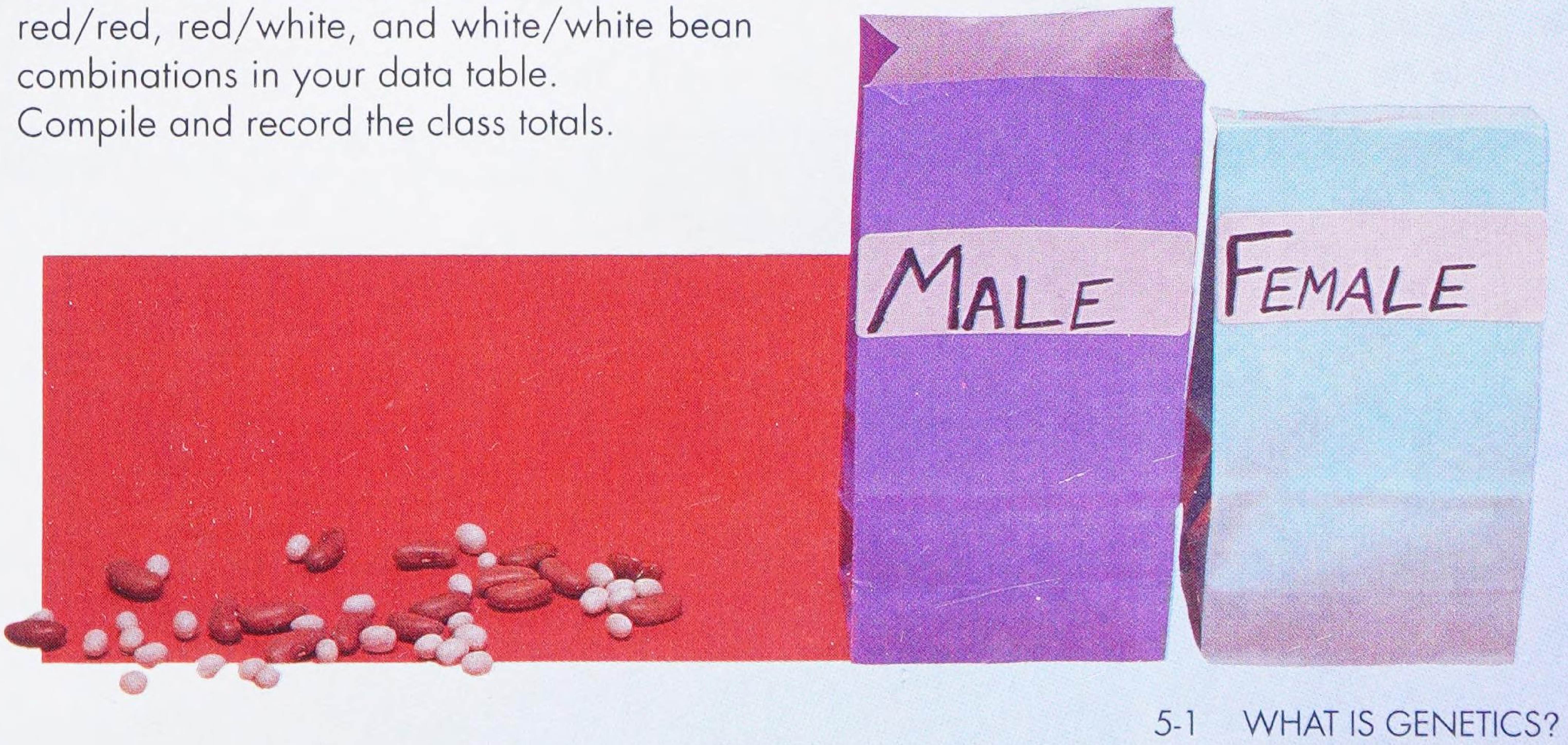
Beans	Red/Red	Red/White	White/White
Total			
Class Total			

Analyze

1. Which combination occurred most often?
2. If red is dominant and white is recessive, how many plants have heterozygous genes?
3. How did your *predicted* (expected) results compare with your *observed* (actual) results?
4. What was the ratio of red/red to red/white to white/white?

Conclude and Apply

5. What are the chances of selecting the same color in a pair of alleles each time?
6. Does chance affect allele combination? Explain.
7. How do the results of a small sample compare with the results of a large sample?
8. **Hypothesize** how you could get predicted results to be closer to actual results.



5-2 Genetics Since Mendel

New Science Words

incomplete dominance
multiple alleles
polygenic inheritance

Objectives

- Explain incomplete dominance.
- Compare multiple allele and polygenic inheritance, and give examples of both.

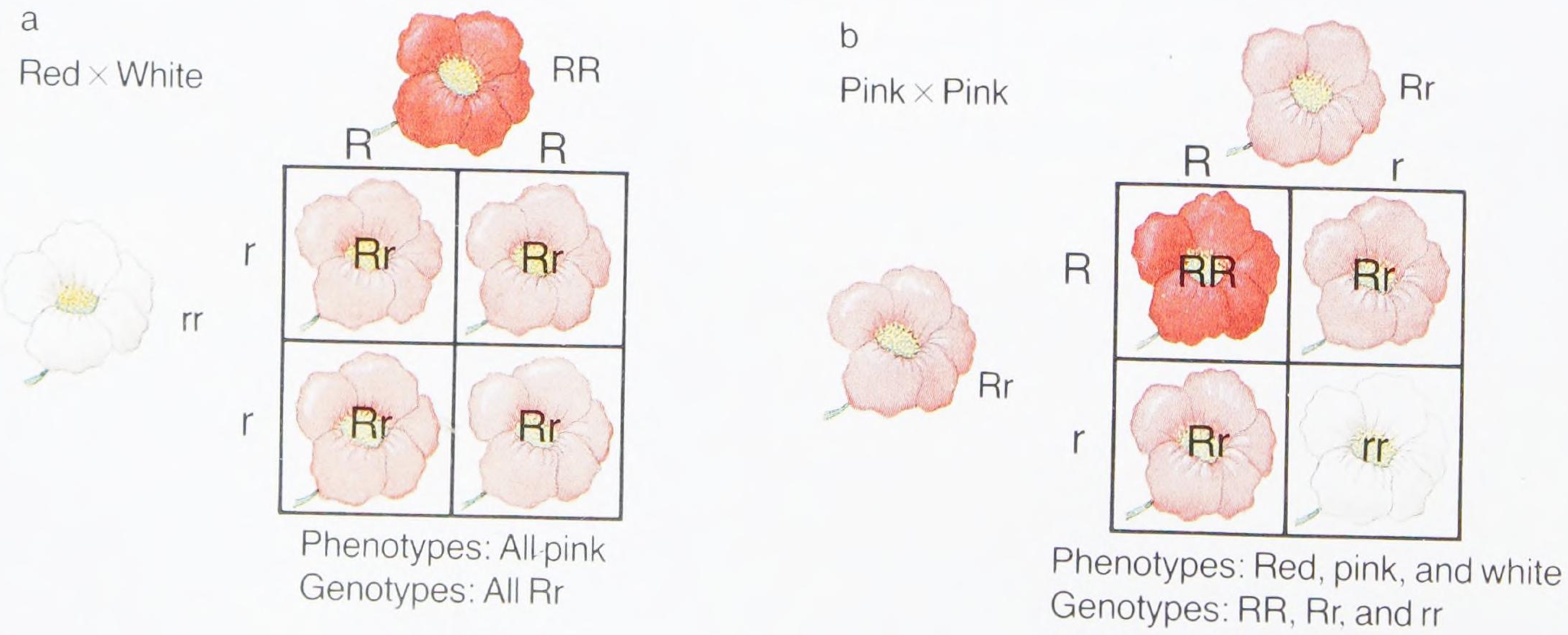
Incomplete Dominance

When Mendel's work was rediscovered, scientists repeated his experiments. Mendel's results proved true for peas and other plants again and again. One scientist, Carl Correns, crossed pure red four o'clock plants with pure white four o'clocks. He expected to get all red flowers. But to his surprise, all the flowers were pink as in Figure 5-8a. Neither allele for flower color seemed dominant. Had the colors become blended like paint colors? He crossed the pink flowered plants with each other and red, pink, and white flowers were produced as in Figure 5-8b. The red and white alleles had not become "blended." When *both* alleles are expressed in offspring, the condition is called **incomplete dominance.** Coat color in cattle and horses and blood type in humans are examples of incomplete dominance.

In Your JOURNAL

In your Journal, write about Barbara McClintock and her work with genes that change position on chromosomes. What organism did she use? How did she make her discovery?

Figure 5-8. The diagram below shows how color in four o'clock flowers is inherited by incomplete dominance. The first generation plants (a) are crossed with each other to obtain the second generation (b).



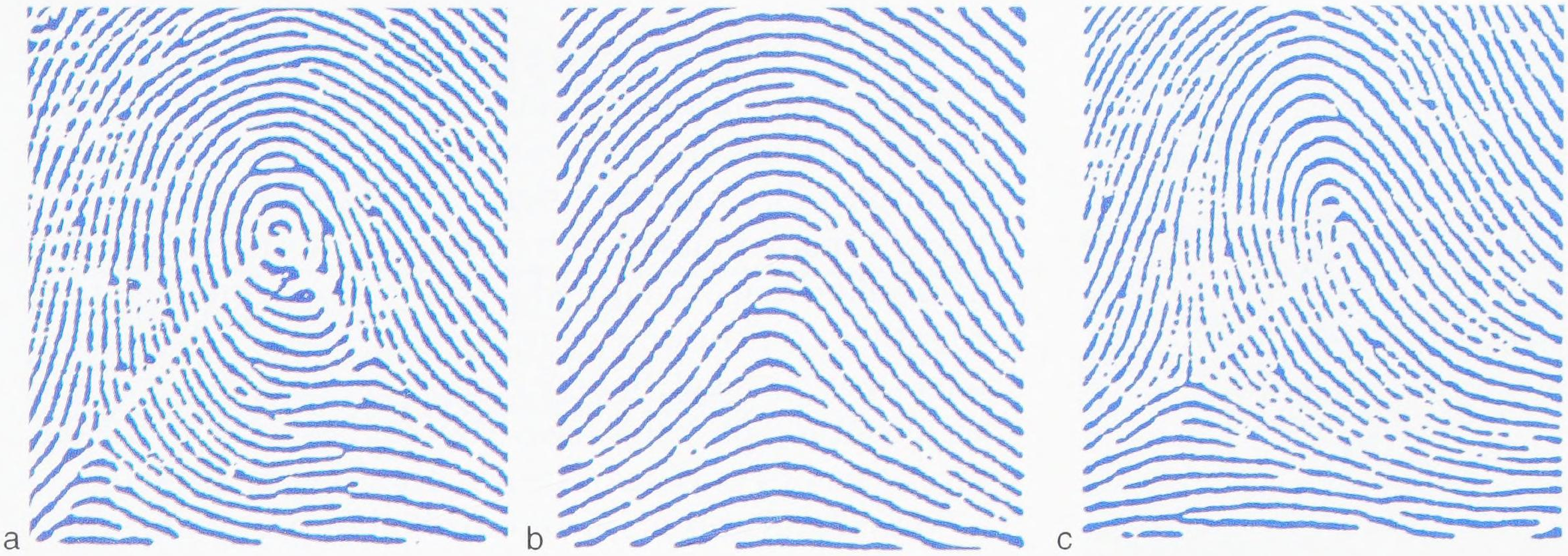


Figure 5-9. Fingerprints in your class will probably show varieties of the whorl (a), arch (b), and loop (c), patterns. There are many variations in these patterns.

Multiple Alleles

Mendel studied traits in peas that had two alleles controlling a trait. However, many traits have more than two alleles, or **multiple alleles,** that control them. In the human population, blood type is a trait that has three alleles.

In 1900, Dr. Karl Landsteiner found three blood types in the human population. He called them A, B, and O. A and B alleles are inherited by incomplete dominance. A person with AB blood type shows both alleles in his or her phenotype. However, both A and B alleles are dominant to the O allele, which is recessive.

Table 5-3 shows the ways in which the alleles for blood type can combine. Notice that a person with phenotype A blood has inherited either the genotype AA or AO. A person with phenotype B blood has inherited either genotype BB or BO. For a person to have type AB blood, an A allele is inherited from one parent and a B allele is inherited from the other parent. Finally, a person with phenotype O blood has inherited an O allele from each parent and has the genotype OO.

Table 5-3

HUMAN BLOOD TYPES

Phenotype	Genotype
A	AA or AO
B	BB or BO
AB	AB
O	OO

MINI-Lab

What are fingerprints?

Fingerprints are formed before birth. The whorl pattern shown in Figure 5-9 is *LL;* the arch pattern is *ll;* the hybrid, or heterozygous, condition is *Ll* and shows a looped pattern. **In your Journal,** *collect data* to see which patterns appear in your class. Explain what type of inheritance is in action in fingerprints.

Figure 5-10. Skin color and eye color in humans are the results of the expression of more than one pair of genes.

Multiple Genes

How many different shades of blue or brown eye color can you detect among your classmates? Eye color is an example of a single trait that is produced by a combination of many pairs of genes. **Polygenic** (pahl ih JEHN ihk) **inheritance** occurs when a group of gene pairs act together to produce a single trait. The effect of each allele may be small, but the combination produces a wide variety. You'll probably have trouble classifying all the different shades of blue or brown eyes in your class.

Many human traits are controlled by polygenic inheritance. Height, weight, body build, and shape of eyes, lips, and ears are traits controlled by polygenic inheritance. It is estimated that skin color is controlled by three to six pairs of genes. Even more gene pairs may control the color of your hair and eyes.

Polygenic inheritance is, of course, not limited to human traits. Grain color in wheat, milk production in cows, and egg production in chickens are polygenic traits also.

The study of genes is no longer a simple look at a single trait controlled by one pair of alleles. Mendel would be astounded if he could see the amount of information that has come from his beginning work.

SECTION REVIEW

1. Compare multiple allele and polygenic inheritance.
2. Explain why a trait inherited by incomplete dominance is not a blend of two alleles.
3. **Apply:** A chicken that is purebred for black feathers is crossed with one that is purebred for white feathers. All the offspring produced have shiny blue feathers. Is this a case of incomplete dominance? Explain.
4. **Connect to Chemistry:** Genes are made of DNA. Find out what the sugar in DNA is called.

Skill Builder

Comparing and Contrasting

Using the information on pages 115 and 116, compare and contrast multiple alleles and multiple genes to explain differences between the two concepts. Include examples of each. If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.

Human Genetics

5-3

Objectives

- Describe two human genetic disorders.
- Explain inheritance of sex-linked traits.
- Explain the importance of genetic engineering.

New Science Words

sex-linked gene
pedigree
genetic engineering

Genes and Health

Sometimes a gene undergoes mutation and results in an unwanted trait. If this happens in a sex cell, then all cells in future generations are affected. In Chapter 4, you learned that there are several types of mutations. Not all mutations are harmful, but some have resulted in genetic disorders among humans. Two disorders discussed here are the result of changes in DNA and are therefore gene mutations. They are sickle-cell anemia and cystic fibrosis.

Sickle-cell anemia (uh NEE mee uh) is a homozygous recessive disorder in which red blood cells are sickle-shaped instead of disc-shaped. Sickle cells can't deliver enough oxygen to the cells in the body. In addition, the misshapen cells don't move through blood vessels easily. Body tissues may be damaged due to insufficient oxygen. Sickle-cell anemia is found in tropical areas and in a small percentage of African Americans.

Cystic fibrosis is another homozygous recessive disorder. Thick mucus is produced in the lungs and digestive system. Mucus in the lungs restricts oxygen intake. In the digestive system, enzymes can't reach food to break it down. Nutrients needed by the body aren't absorbed by body cells. However, with physical therapy exercises and improved medication, the lives of cystic fibrosis patients are being extended.

Did You Know?

In Africa, people who are heterozygous for sickle-cell condition appear to be better protected against malaria than people with normal disc-shaped red blood cells.

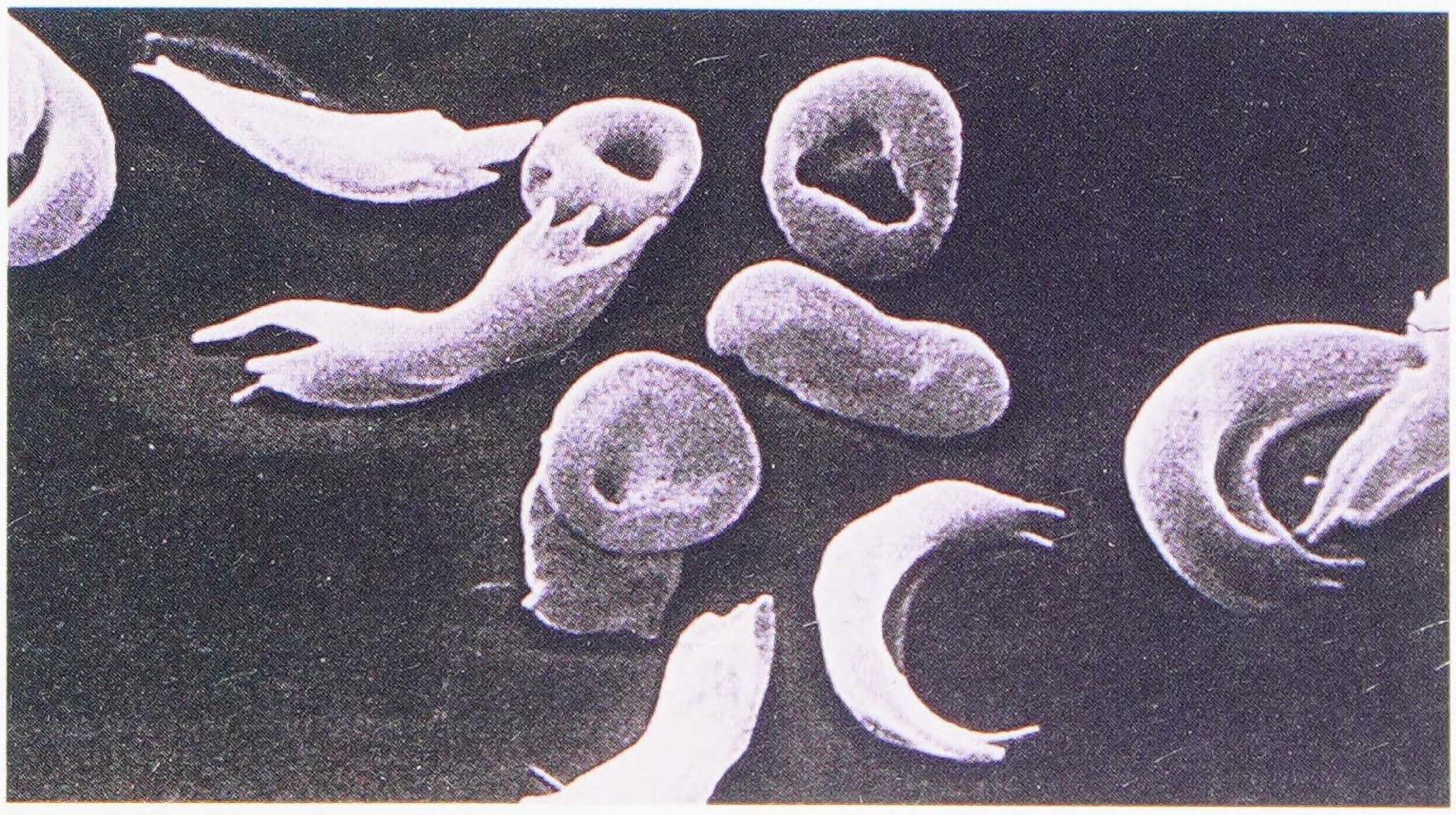


Figure 5-11. In sickle-cell anemia, red blood cells are misshapen.

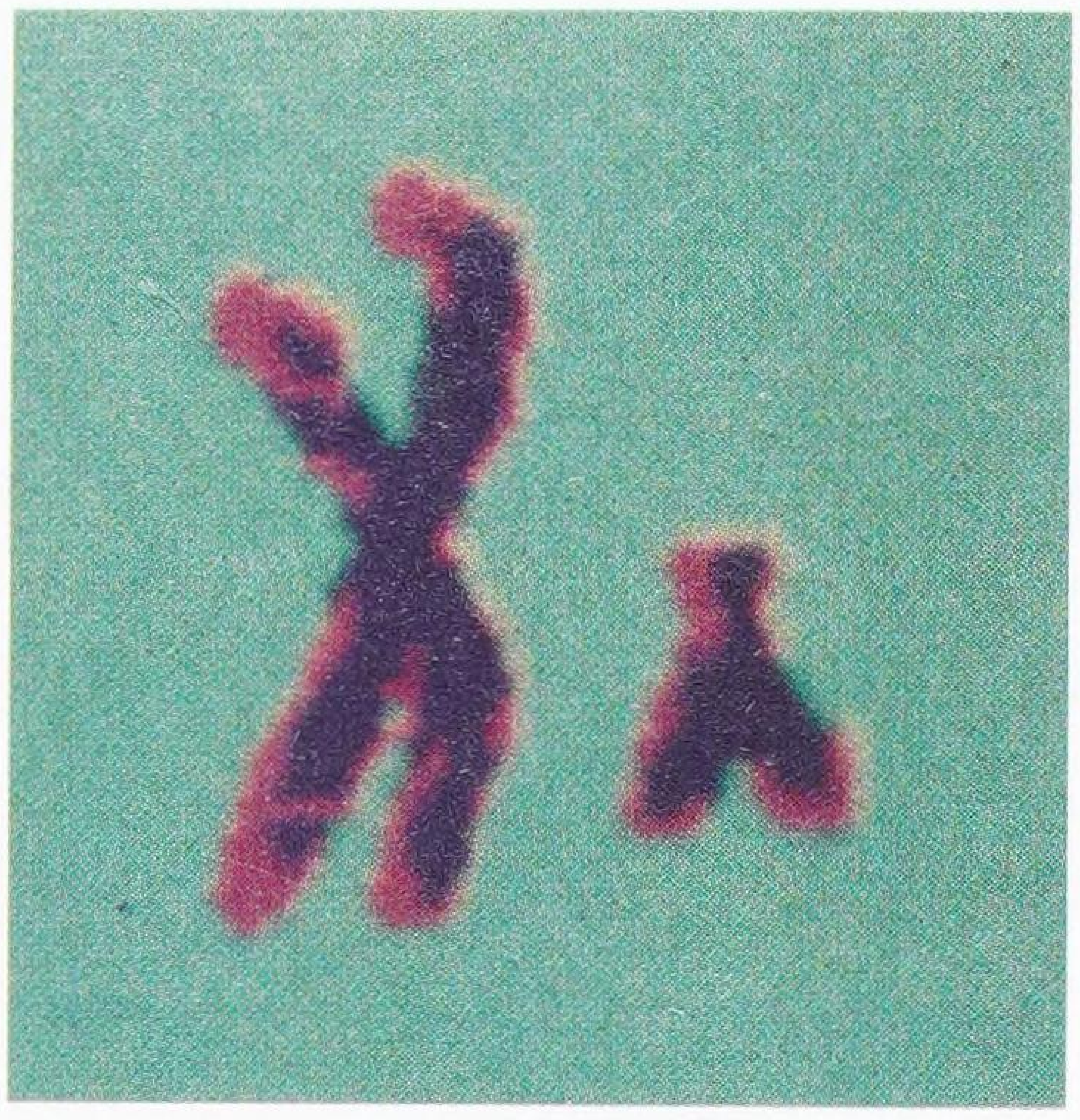


Figure 5-12. Sex in many organisms is determined by X (left) and Y (right) chromosomes. In the photograph above, you can see how X and Y chromosomes differ from one another in size.

Sex Determination

What determines the sex of an individual? Information on sex inheritance in many organisms, including humans, came from a study of fruit flies. Fruit flies have eight large chromosomes in their cells. They contain an X chromosome and a Y chromosome. By 1910, several scientists had concluded that the X and Y chromosomes contained genes that determine the sex of an individual. Females have two X chromosomes in their cells. Males have an X chromosome and a Y chromosome.

Females produce eggs that have only an X chromosome. Males, on the other hand, produce both X-containing sperm and Y-containing sperm. When an egg from a female is fertilized by an X sperm, the offspring is XX, a female. When an egg from a female is fertilized by a Y sperm, the zygote produced is XY, and the offspring is a male. What pair of sex chromosomes is in each of your cells?

PROBLEM SOLVING

Boy or Girl?

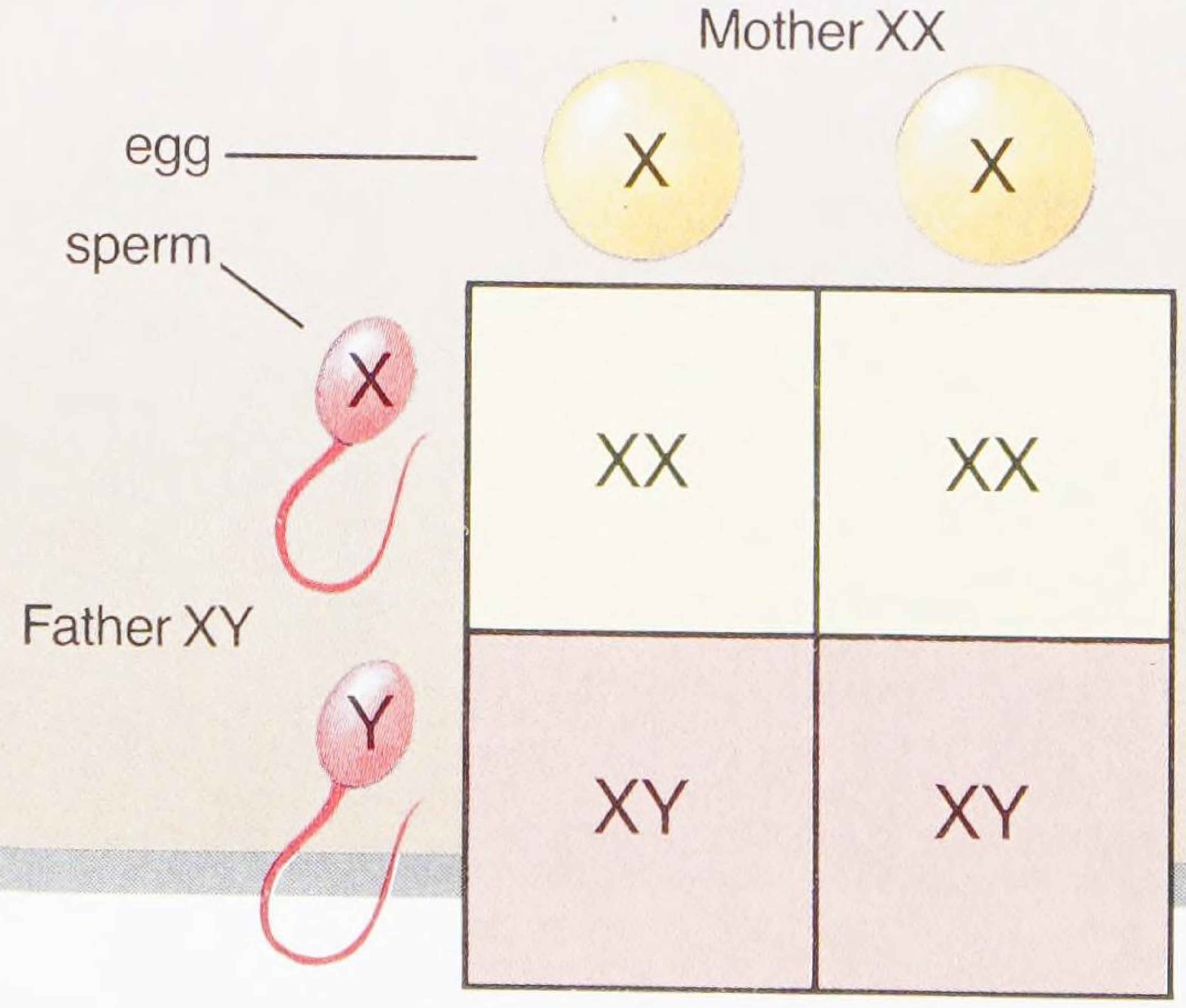
What is the probability of all children in a family being girls? Probability refers to the chance that an event will occur. For example, if you flip a coin, it will land in only one of two ways—heads or tails. The probability of the coin landing heads or tails is one out of two, or one-half, or 50 percent.

If you were to toss two coins at the same time, each coin still has only a one-half probability of landing with heads or tails up. Look at the combinations that could occur in a two-coin toss. The probability of each combination is the product of the probability of each. In the two-coin toss, the probability of both coins turning up heads is the product of the two, or:

$$1/2 \times 1/2 = 1/4$$

Jennifer's mother is going to have a baby. Jennifer already has a sister, so she really hopes this baby is a boy. What is the probability that the baby will be a boy?

Think Critically: What is the probability of a family having three female children in a row?



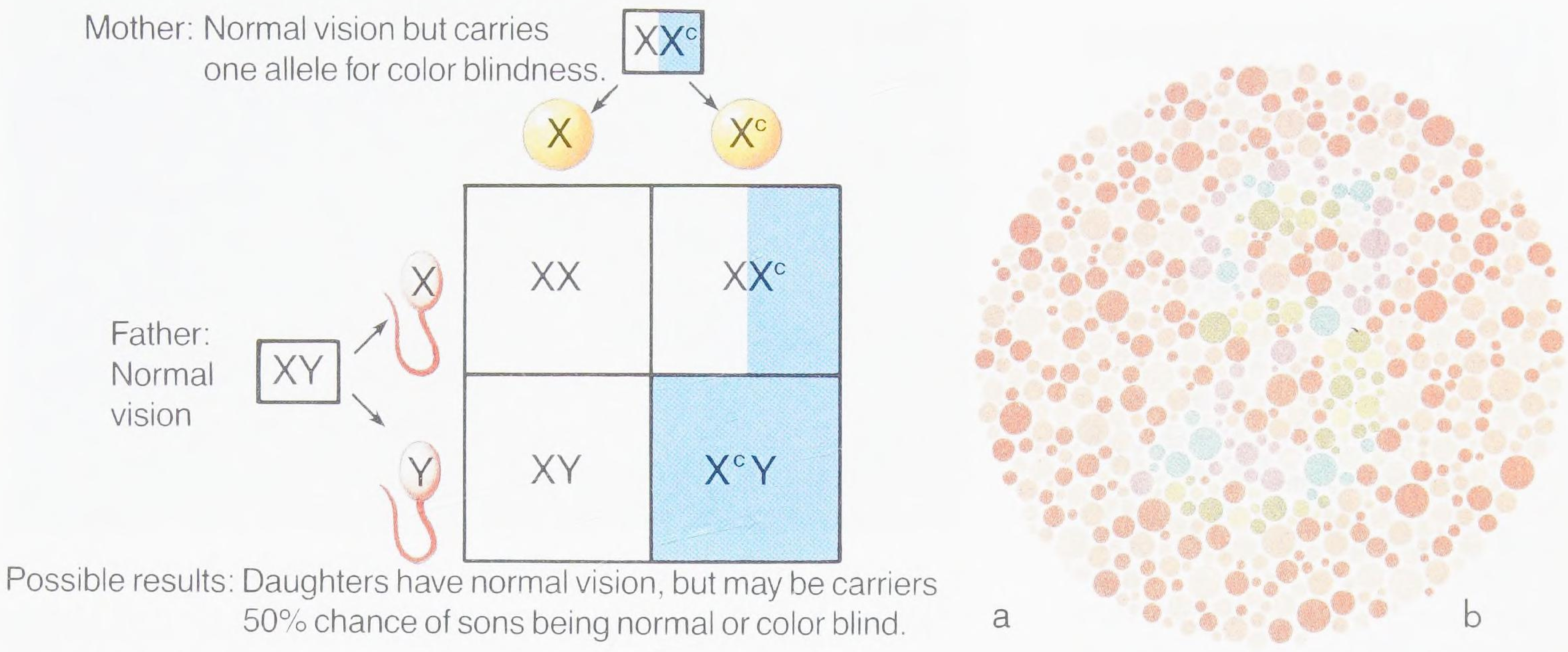

Mother: Normal vision but carries one allele for color blindness.
XX^c
X
X^c
Father: Normal vision
XY
X
Y
XX
XX^c
XY
X^cY
Possible results: Daughters have normal vision, but may be carriers
50% chance of sons being normal or color blind.
a
b

Figure 5-13. Color blindness is a sex-linked trait. Females who are heterozygous see colors normally, but their sons may be color-blind (a). In an eye examination, a color-blind person will see a different number in the disc above (b) than a person with normal color vision.

Sex-linked Disorders

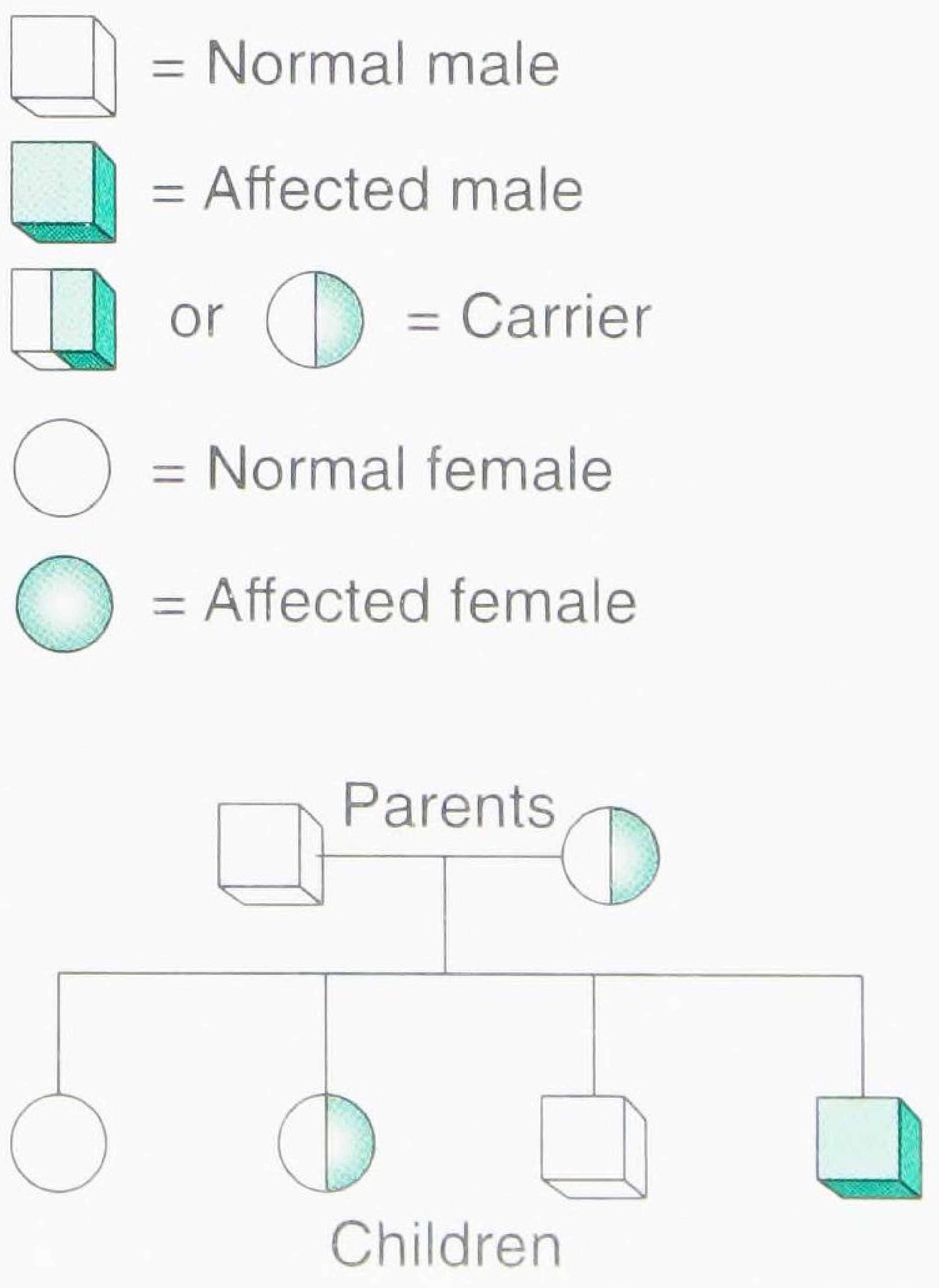
Some inherited conditions are closely linked with the X and Y chromosomes that determine the sex of an individual. A story is told that a young boy appeared to have normal intelligence, but couldn't be taught to pick ripe cherries on the family farm. His parents took him to a doctor. After observing him, the doctor concluded that the boy couldn't tell the difference between the colors red and green. Individuals who are red-green color-blind have inherited an allele on the X chromosome that prevents them from seeing these colors.

An allele inherited on a sex chromosome is a **sex-linked gene.** More males are color-blind that females. Can you figure out why? If a male inherits an X chromosome with the color-blind allele from his mother, he will be color-blind. Color-blind females are rare.

Another sex-linked gene disease is hemophilia (hee muh FIHL ee uh), a disorder in which blood does not clot properly. A scrape can be life threatening. Like color-blindness, males who inherit the X chromosome with the hemophilia allele will have the disorder. For a female to be a hemophiliac, she must inherit the defective allele on both X chromosomes. Hemophilia occurs in fewer than 1 in 7000 males. Females are usually just carriers.

How can you trace a trait through a family? A **pedigree** is a tool for tracing the occurence of a trait in a family. Males are represented by squares and females by circles. A solid circle or square shows that the person has the condition. Half colored circles or squares indicate carriers. A carrier has an allele for a trait, but does not show the trait.

Figure 5-14. Pedigrees show the occurrence of a trait in a family.


= Normal male
= Affected male
or
= Carrier
= Normal female
= Affected female
Parents
Children

Why Is Genetics Important?

If Mendel were to pick up a daily newspaper in most countries today, he probably wouldn't believe his eyes. There is hardly a day that goes by anymore that there isn't a news article about the latest information on genetic research. The word *gene* has become a household word. In this chapter, you have learned that every trait that you have inherited is the result of genes expressing themselves. The same laws that govern inheritance of traits in humans govern the inheritance of traits in watermelons, wheat, and mice as well.

In this section on human genetics, you've seen that there are inherited disorders that affect the human population. You may even know someone with one of these disorders. Many genetic disorders are controlled by diet and preventive measures. Genetics is no longer something that you can read about only in textbooks.

Connect to... Chemistry

Knowledge of genetic disorders has reached soft drink cans! Persons who have not inherited the enzyme to break down phenylalanine are warned about the presence of this chemical in certain artificially sweetened drinks. Find out what happens to people born with PKU.

TECHNOLOGY

Karyotyping

Karyotyping is a process that allows scientists to study the chromosomes of an individual, sometimes even before birth.

Chromosomes are best seen during prophase in mitosis when they are tightly coiled. Skin cells divide frequently, so these cells are good to use for making a karyotype. The cells are fixed on microscope slides and dyed so that light and dark bands appear showing the position of DNA along the chromosomes. Then a photograph is taken of the chromosomes. The photograph is cut up into individual chromosomes. Scientists use the pattern of the stained bands, chromosome length, and the position of centromeres to identify pairs of matching chromosomes. Each pair is also numbered. The bands enable scientists to see if chromosomes have missing or duplicated parts.

Some genetic disorders can be identified just by looking at the karyotype of an individual. Sometimes this is done before birth when cells are taken from fluid around a fetus.

Think Critically: Why would a missing part of a chromosome affect the traits an individual would have?

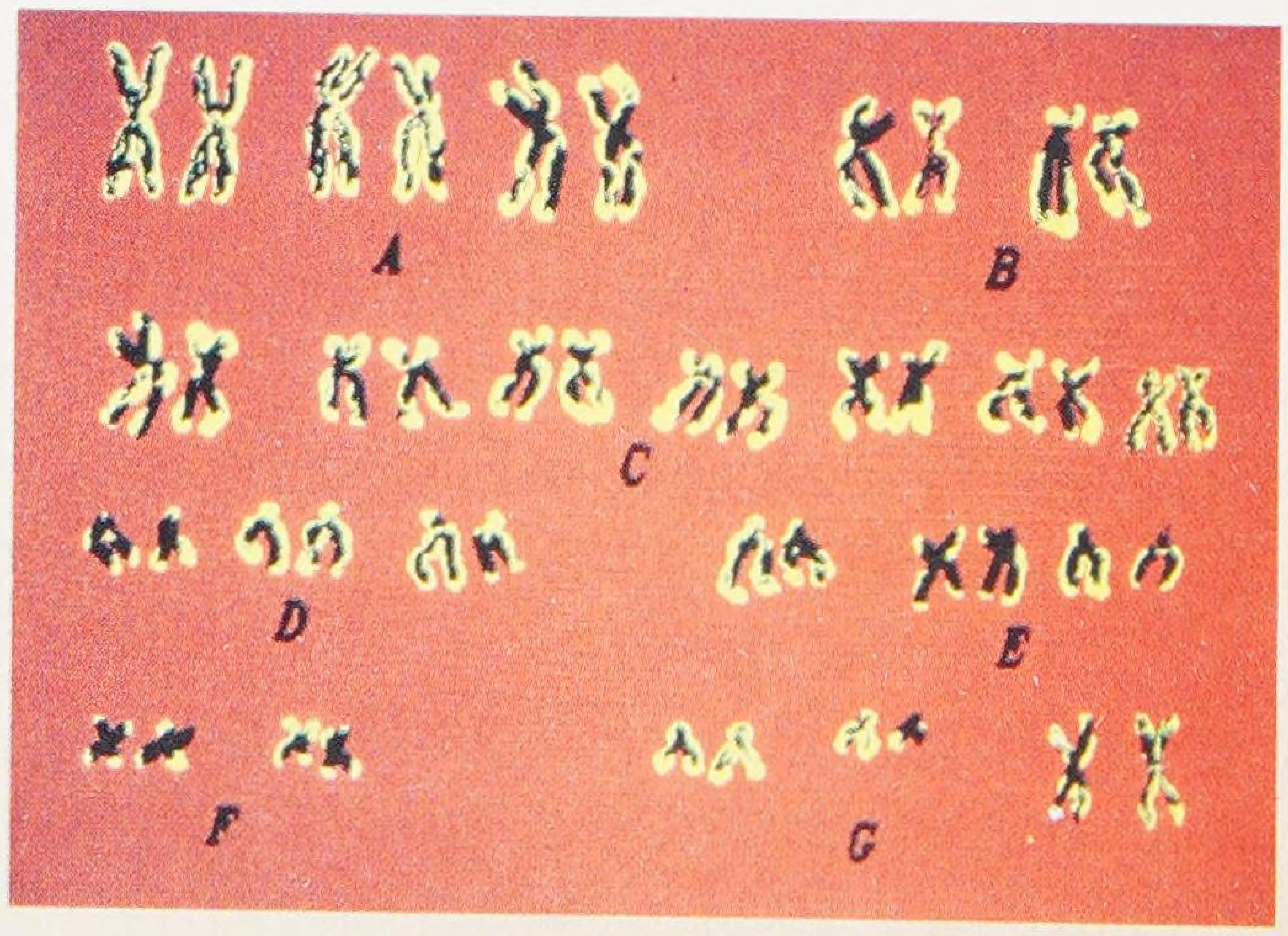


Figure 5-15. Genetically engineered bacteria are being developed to clean up environmental problems such as oil spills.

Knowing how genes are inherited now causes some people to seek the advice of genetic counselors before having children. For those with children with genetic disorders, there are high hopes for cures through research.

Through **genetic engineering**, scientists are experimenting with methods that allow them to go into cells to change or correct specific damaged or mutated genes. Genetic engineering is already used to help produce large quantities of medicine, such as insulin, to meet the needs of people with the disease diabetes. In addition, genetic engineering research is being used to find new ways to provide people with more nutritious food.

What is genetic engineering?

In Your JOURNAL

Hugh de Vries, Carl Correns, Walter Sutton, and Thomas Hunt Morgan each made discoveries in the field of genetics. Summarize their work **in your Journal,** and give the importance of their contributions.

SECTION REVIEW

1. Describe two genetic disorders.
2. Explain why males are affected more often than females by sex-linked genetic disorders?
3. Describe the importance of genetic engineering.
4. **Apply:** Use a Punnett square to explain how a woman who is a carrier for color blindness can have a daughter who is color-blind.
5. **Connect to Chemistry:** Find out how chemistry is used in genetic engineering.

Skill Builder

Concept Mapping

Use a network tree concept map to show how X and Y sex cells can combine to form zygotes. Begin with female sex cells each containing an X chromosome. Use two male sex cells. Indicate one with an X chromosome and one with a Y chromosome. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

SCIENCE & SOCIETY

5-4 The Human Genome

New Science Words

genome

Objectives

- Describe the goal of the Human Genome Project.
- Explain some advantages and disadvantages of genetic research.

Tracking Human Genes

What is a genome?

Think of the DNA that makes up your chromosomes. It is somewhat like a long railroad track. Just as railroad engineers use maps showing the various towns along rail routes, genetic engineers also are now able to locate particular genes along each chromosome. The resulting chromosome map, or **genome,** is a chart that shows the location of individual genes on a chromosome. A project called the *Human Genome Project* is aimed at mapping all the genes on all the human chromosomes. In all, there are about 100 000 genes on the 46 chromosomes in each of the body cells of your body. Codes for part of about 5000 genes are known.

Much like a railroad engineer who stops at a specific station, scientists who study chromosomes are able to follow a piece of DNA and stop at the spot where a gene is located. Using chromosome maps, they can identify genes responsible for specific traits.

Why would such a map be useful? More than 3000 human disorders are known to be inherited, including cystic fibrosis, muscular dystrophy, and cancers caused by chemicals that change DNA. By examining a few drops of blood, scientists will be able to examine all chromosomes and find genes that code for certain disorders. After examining a person's genes, a doctor can tell if that person has a certain disorder. Doctors are then able to suggest measures to avoid development of the disorder. A person showing an inherited heart disease may begin a stress management program to reduce the chances of having a heart attack. Others might decide not to have children based on the information in their genome.

Connect to...

Physics

It is calculated that there are more than a billion base pairs in the DNA sequence of the human genome. Without integrated circuits and microchips developed from studies in physics, the computers needed to collect and store this data would not be possible. Besides storing DNA data, what other uses are there for computers in biology?

This information may save lives, but there are other facets to consider with this new technology. For example, what if company officials wanted to examine the genome of anyone who applied to them for a job? This information might be able to identify inherited traits that would affect job performance. An airline company might be unwilling to hire a person who is genetically inclined to suffer from alcoholism. This technology may help prevent the development of many disorders, but is it fair to deny a job to someone who *may* develop a disorder?

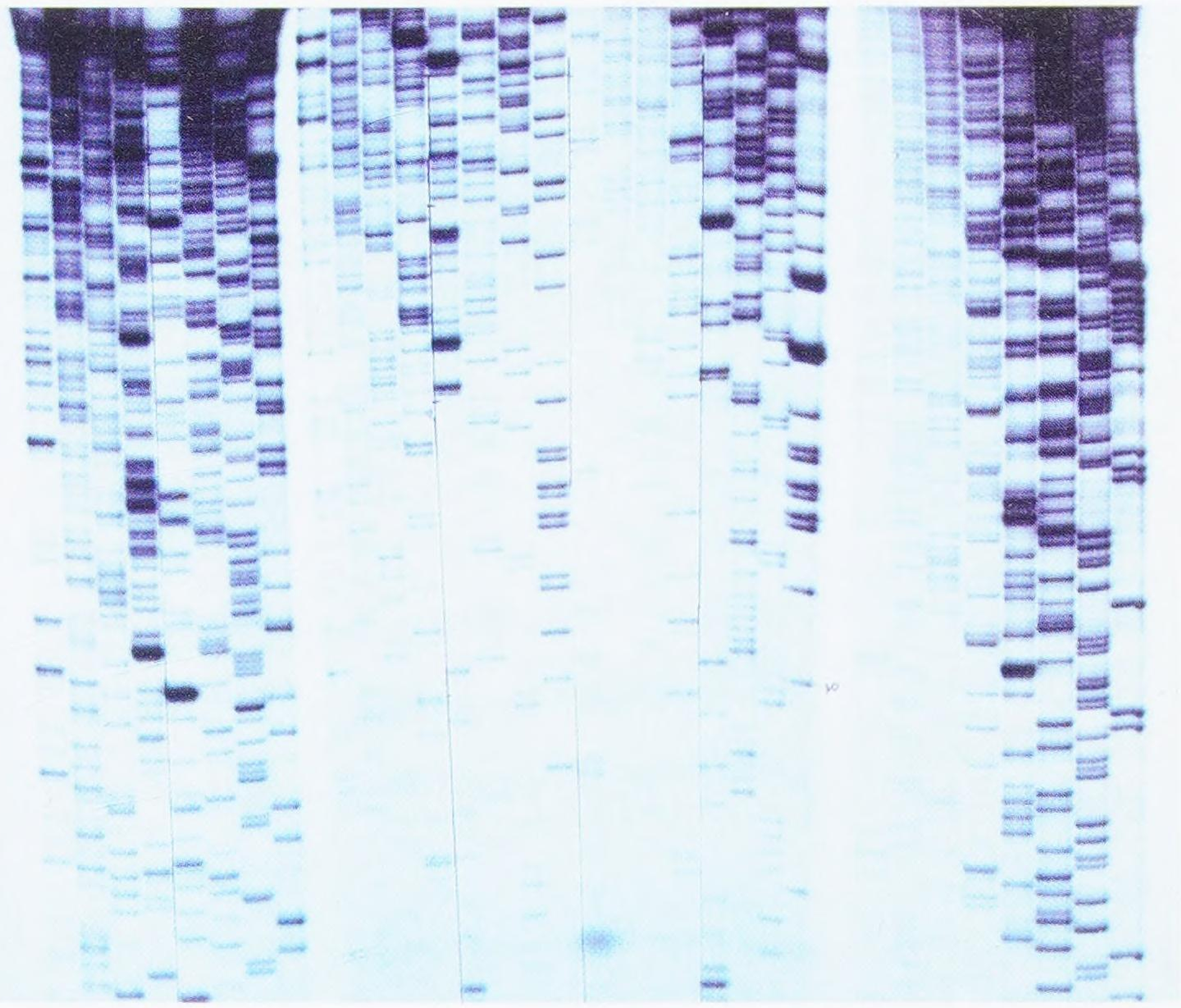


Figure 5-16. Studies of parts of chromosomes can be used to produce chromosome maps that show where specific genes are located.

What if a handicap or an inheritable disorder could be spotted while a child is still young? Early detection would allow therapy that could permit a much more enjoyable life.

Most scientists agree that the benefits of the Human Genome Project will far outweigh the costs. Such large research projects almost always result in other technologies that can be used in other sciences. Knowing the location and DNA code of some genes may even make it possible to cure human genetic disorders in the future.

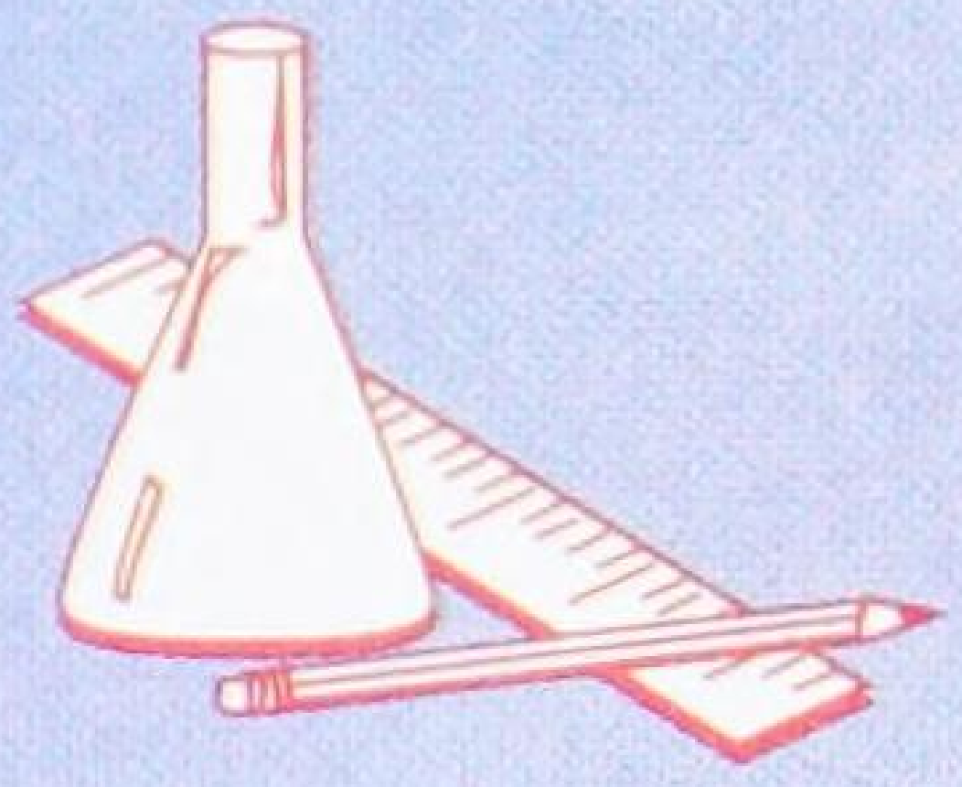
SECTION REVIEW

1. What is the purpose of the Human Genome Project?
2. List one possible advantage and one possible disadvantage of this type of technology.

You Decide!

SCIENCE & SOCIETY

Although the human genome initiative could mean good things for people with genetic disorders, the use of such technology may cause problems. Some genetic traits may hinder an individual's ability to perform a job safely. Do you feel that an employer should be given the right to use genetic information to judge an individual's ability to perform a job?



ACTIVITY 5-2

Determining Polygenic Inheritance

Problem: *How can the effect of polygenic inheritance be determined?*

Materials

- metric ruler
- graph paper
- pencil

Procedure

1. Make a **hypothesis** about what a bar graph will look like that shows the heights of the students in your class.
2. Measure the height of every student in the class to the nearest centimeter.
3. Record the height of each student.
4. Make a table on your paper like the one shown. Count the number of students for each interval and complete the table.
5. *Plot* the results from the table on a bar graph. The height should be graphed on the horizontal axis and the number of students of each height along the vertical axis.

Data and Observations

Height in cm	Number of Students
A 101 - 110	
B 111 - 120	
C 121 - 130	
D 131 - 140	
E 141 - 150	
F 151 - 160	
G 161 - 170	
H 171 - 180	

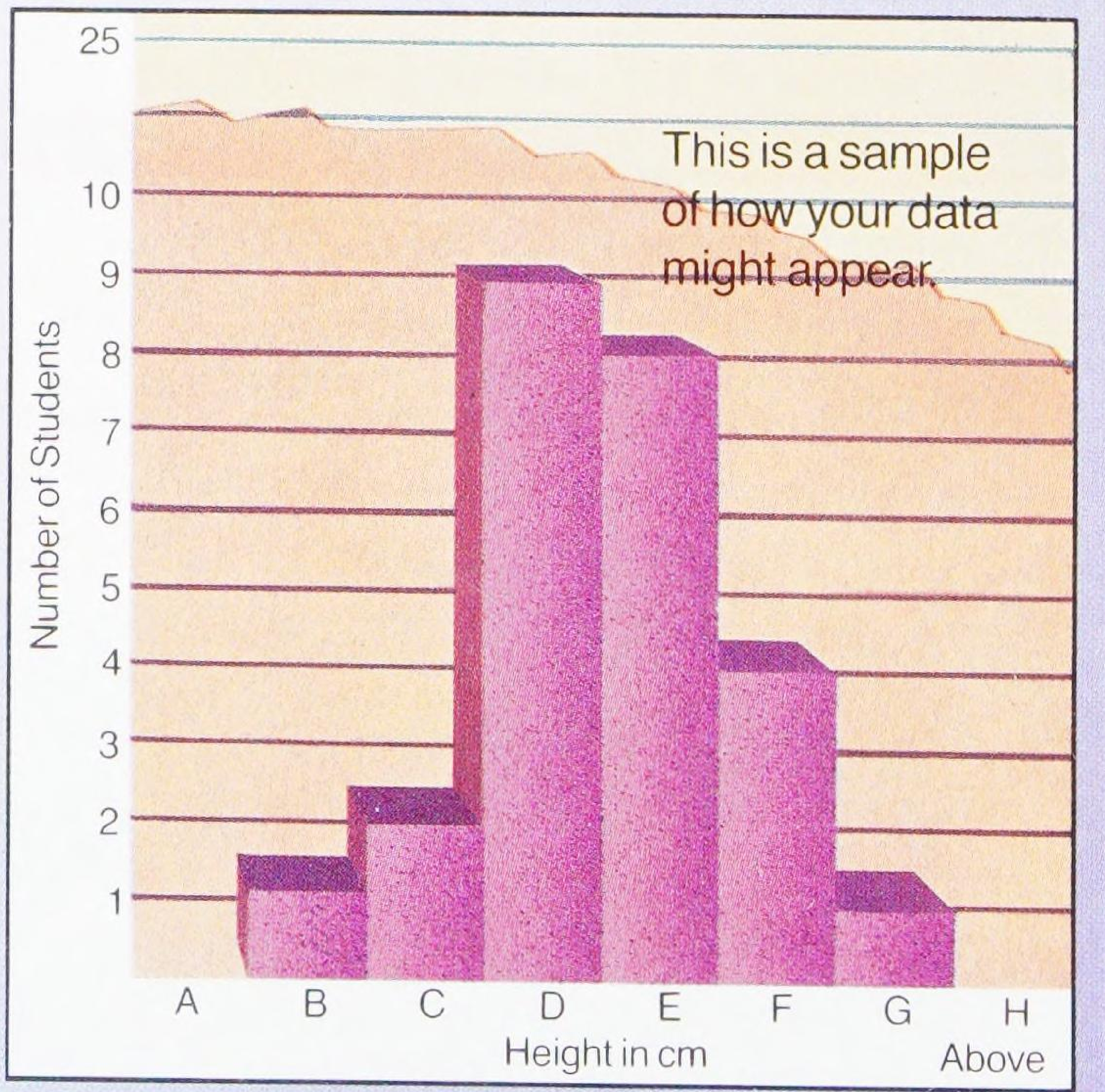
6. The *range* of a set of data is the difference between the greatest measurement and the smallest measurement. The *median* is the middle number when the data are placed in order. The *mean* is the sum of all the data divided by the number of addends. The *mode* is the number that appears most often in the measurements. Calculate each of these numbers.

Analyze

1. What is the range of the heights in your class?
2. What is the median height in your class?
3. What is the mean of the heights in your class?
4. What is the mode of the heights in your class?

Conclude and Apply

5. What does the bar graph look like?
6. How can you tell if a trait is controlled by more than one gene?
7. Can you *infer* from your data that height is controlled by more than two genes?



This is a sample of how your data might appear.

CHAPTER REVIEW

SUMMARY

5-1: What Is Genetics?

1. Traits are inherited through alleles passed from one generation to the next. Gregor Mendel determined the basic laws of genetics through controlled experiments.

2. The probability of types of offspring from parents can be predicted by using Punnett squares.

3. Genotype is the genetic makeup of an organism for a trait. Phenotype is the physical appearance that results from the genotype.

5-2: Genetics Since Mendel

1. When a trait is inherited by incomplete dominance, neither allele is completely dominant.

2. With multiple alleles, there are more than two alleles controlling a trait. In polygenic inheritance, more than one pair of alleles controls a trait. Eye and hair color are determined by polygenic inheritance.

5-3: Human Genetics

1. Hemophilia and cystic fibrosis are genetic disorders.

2. Color blindness and hemophilia are located on the X chromosomes. Males express sex-linked traits more than females. Pedigrees may show patterns of inheritance in a family.

3. Genetic engineering may be used to correct mutated genes, cure disease, and produce medicine and food.

5-4: Science and Society: The Human Genome

1. The Human Genome Project seeks to locate and identify all the genes on human chromosomes.

2. Genome information may help pinpoint specific genetic disorders.

KEY SCIENCE WORDS

a. **alleles**
b. **dominant**
c. **genetic engineering**
d. **genetics**
e. **genome**
f. **genotype**
g. **heredity**
h. **heterozygous**
i. **homozygous**
j. **incomplete dominance**
k. **multiple alleles**
l. **pedigree**
m. **phenotype**
n. **polygenic inheritance**
o. **Punnett square**
p. **recessive**
q. **sex-linked gene**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. technology for changing a gene
2. gene located on the X chromosome
3. the allele that is hidden
4. different forms of the same gene
5. a tool for predicting possible offspring
6. an allele that does not show completely
7. the study of heredity
8. more than one pair of alleles controls a trait
9. shows the pattern of gene inheritance in a family
10. all the genes in a species

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. ______ are located on chromosomes.
   - **a.** DNA codes
   - **c.** Carbohydrates
   - **b.** Pedigrees
   - **d.** Zygotes
2. Color blindness results from an allele that is ______.
   - **a.** dominant
   - **b.** on the Y chromosome
   - **c.** on the X chromosome
   - **d.** present only in females
3. ______ results when two alleles both appear in the phenotype.
   - **a.** Incomplete dominance
   - **b.** Polygenic inheritance
   - **c.** Multiple alleles
   - **d.** Sex-linked genes
4. During meiosis, ______ for a trait separate.
   - **a.** proteins
   - **c.** alleles
   - **b.** cells
   - **d.** pedigrees
5. The major job of genes is to control ______.
   - **a.** chromosomes
   - **c.** cell membranes
   - **b.** mitosis
   - **d.** making proteins
6. Blood type is inherited through ______.
   - **a.** polygenic inheritance
   - **b.** multiple alleles
   - **c.** incomplete dominance
   - **d.** recessive genes
7. Sickle-cell anemia is inherited through ______.
   - **a.** polygenic inheritance
   - **b.** multiple alleles
   - **c.** incomplete dominance
   - **d.** recessive genes
8. Eye color is a trait inherited through ______.
   - **a.** polygenic inheritance
   - **b.** multiple alleles
   - **c.** incomplete dominance
   - **d.** recessive genes
9. A female is produced if an egg unites with a sperm containing ______.
   - **a.** an X chromosome
   - **c.** a Y chromosome
   - **b.** XX chromosomes
   - **d.** XY chromosomes
10. Punnett squares are used to ______ the outcome of crosses of traits.
    - **a.** dominate
    - **c.** assure
    - **b.** predict
    - **d.** number

USING LAB SKILLS

11. Using the information on fingerprint inheritance in the Mini-Lab on page 115, have at least ten classmates *volunteer* to see how patterns have been inherited in their families. Data in the form of fingerprints might be collected from family members and pedigrees drawn.
12. In the activity on page 124, you graphed a class trait controlled by polygenic inheritance. Perform a similar experiment testing hand spans. Find the mode, range, and median for your class. Record this data in your Journal and graph your results on a line graph.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Compare and contrast multiple allele inheritance and polygenic inheritance.
14. Explain the importance of Mendel's experimental methods.
15. Using an example, explain how blood typing could be used to detect the correct parent of a newborn if there was a mix-up in a nursery.
16. What is the difference between homozygous and heterozygous?

17. Explain why dominant traits might not necessarily be the traits that show up most frequently.

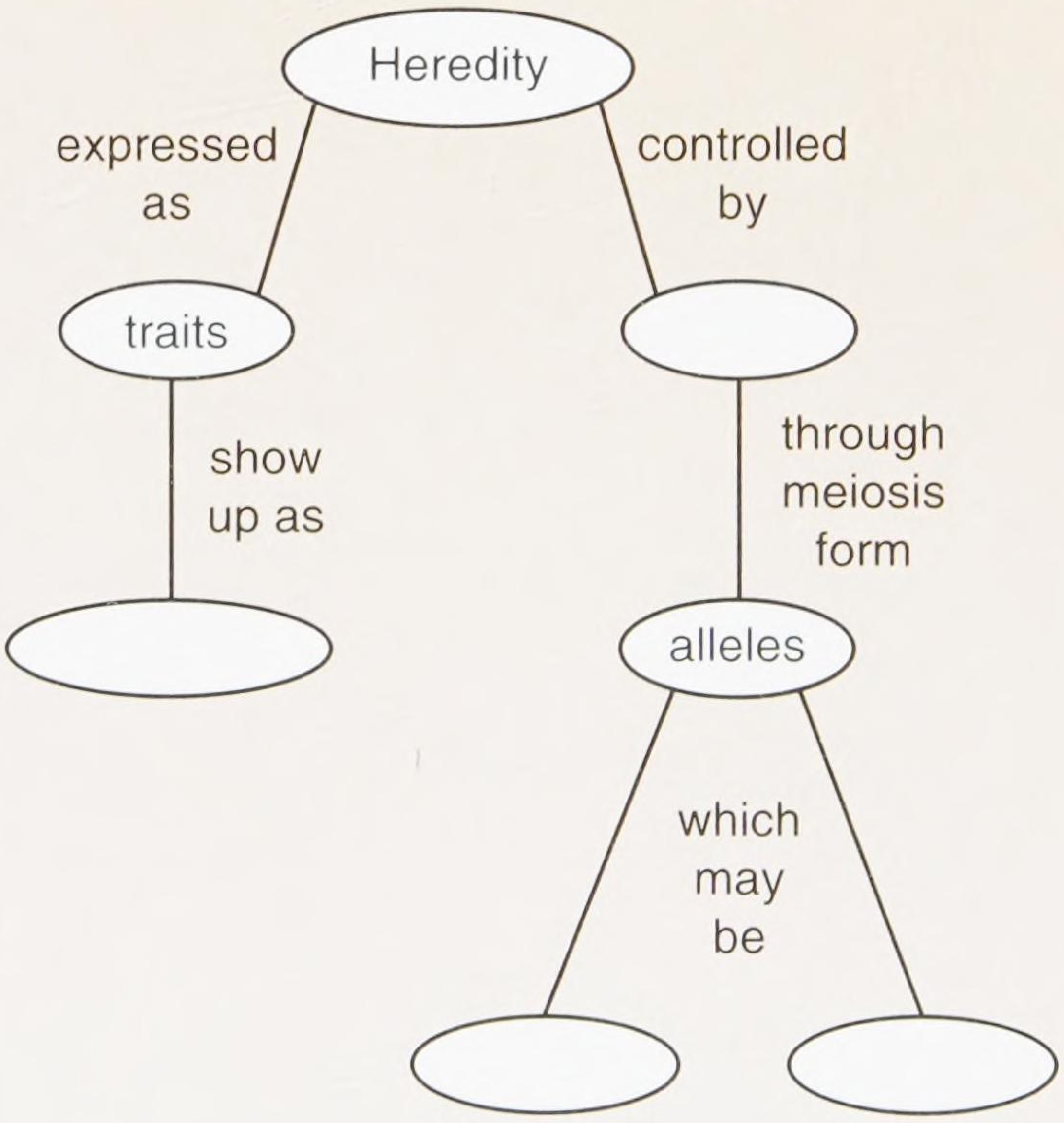
APPLY

18. A pure black guinea pig is crossed with a pure white guinea. All the offspring are black. What are the genotypes of the parents and the offspring?
19. In breeding Andalusian variety chickens, farmers found that chickens with black feathers always had chicks with black feathers, and chickens with white feathers always had chicks with white feathers. But, mating a black with a white chicken produced some chickens with blue feathers. How can this trait be explained?
20. Explain the relationship between DNA, genes, alleles, and chromosomes.
21. How will finding the location of disease-causing genes on chromosomes help to cure genetic diseases?
22. Explain how an organism that has a genotype *Gg* could have the same phenotype as an organism with the genotype *GG*.

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Designing an Experiment:** Design an experiment to determine if a trait is transmitted by a dominant or recessive gene.
2. **Recognizing Cause and Effect:** A mutation in the gene for normal production of a plant's chlorophyll results in a plant with no chlorophyll. Explain the consequences.
3. **Classifying:** Classify the type of inheritance of each human trait by making a chart: blood type, color blindness, eye color, height, hemophilia, sickle-cell anemia, weight.
4. **Interpreting Scientific Illustrations:** What genotypes and phenotypes would be produced if you crossed a red offspring with a pink offspring from Figure 5-8b on page 114?
5. **Concept Mapping:** On a separate sheet of paper, use the following terms to complete the network tree concept map below: phenotype, recessive genes, dominant.



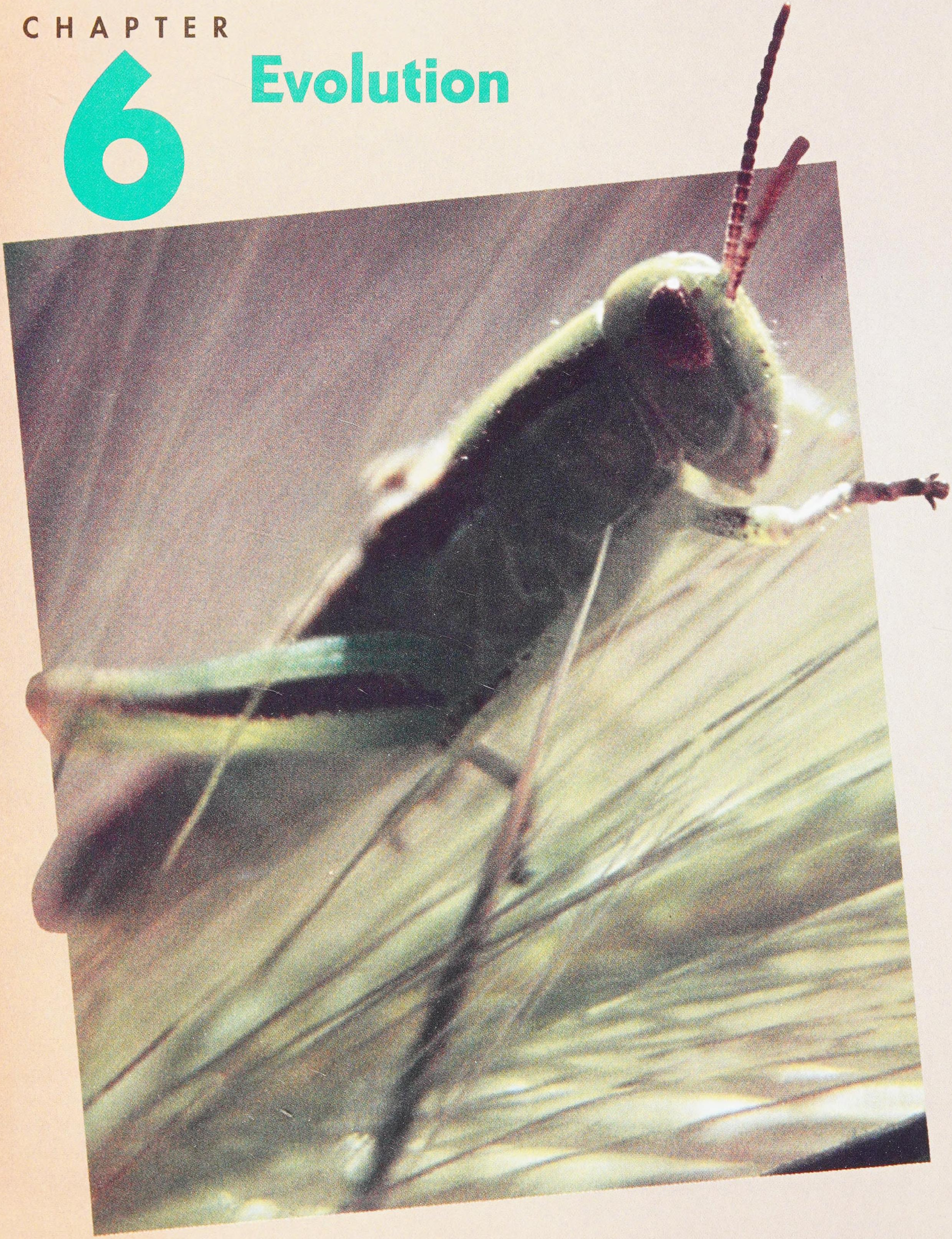
PROJECTS

1. Research a genetic disease such as cystic fibrosis. How is it inherited? Who does it affect? How can it be detected? What are its symptoms? How is it treated? Share your findings with the class in a written report.
2. Research sex determination in birds, butterflies, and frogs to find out how it differs from sex inheritance in humans.

CHAPTER

6

Evolution



Have you ever wondered why some grasshoppers are green? Do you know why polar bears are white and grizzly bears brown?

FIND OUT!

Do this activity to find out why some organisms are the color they are. Record all data in your Journal.

Spread out a sheet of newspaper want ads on the floor. Cut ten 2 cm by 2 cm squares diagonally out of another sheet of want ads, a sheet of black paper, and a sheet of white paper. Scatter the 30 squares randomly across the sheet of newspaper on the floor. Have a partner time you for 10 seconds, and pick up squares from the newspaper. Count and record the number of squares of each color you picked up. Return the squares to the newspaper. Repeat this process three times. Average your results. If the squares represent organisms in an environment, *infer* which ones would most likely not be found. Why do you think you don't notice green grasshoppers easily?

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 6-1 Mechanisms of Evolution
- ▶ Early Theories of Evolution
- ▶ Evolution by Natural Selection
- ▶ Adaptation and Variation
- ▶ How Fast Does Evolution Occur?

Section 6-2 Evidence for Evolution
- ▶ Fossil Evidence
- ▶ The Fossil Record
- ▶ Other Evidence for Evolution

Section 6-3 Science and Society
Plant and Animal Extinction
- ▶ Causes of Extinction
- ▶ Ways to Prevent Extinction

Section 6-4 Human Evolution
- ▶ Primates
- ▶ Human Ancestors
- ▶ Modern Humans

Previewing Science Skills

- ▶ In the **Skill Builders**, you will classify, use tables, and make a concept map.
- ▶ In the **Activities**, you will collect and organize data, interpret data, formulate models, hypothesize and experiment.
- ▶ In the **MINI-Labs**, you will make and use models and infer.

What's next?

In nature, organisms that are well suited to their environment have a better chance of surviving than those that aren't. In this chapter, you will learn why organisms live where they do and how organisms change. You will also learn about the process of evolution.

6-1 Mechanisms of Evolution

New Science Words

species
evolution
natural selection
variation
population
gradualism
punctuated equilibrium

Objectives

- Compare and contrast Lamarck's theory of evolution with Darwin's.
- Explain the importance of variations in organisms.
- Relate how gradualism and punctuated equilibrium describe the rate of evolution.

Early Theories of Evolution

On Earth today there are millions of different types of organisms. Included among these are different species of plants, animals, bacteria, fungi, and protozoa. A **species** is a group of organisms whose members look alike and successfully reproduce among themselves. Have any of these species of organisms changed since they first appeared on Earth? Are they still changing today? Evidence from observation and experimentation shows that living things have changed through time and are still changing. Change in the hereditary features of a type of organism over time is **evolution.** Figure 6-1 shows how the horse has changed over time.

Figure 6-1. The evolution of the horse. Notice the change from several toes to a single hoof.

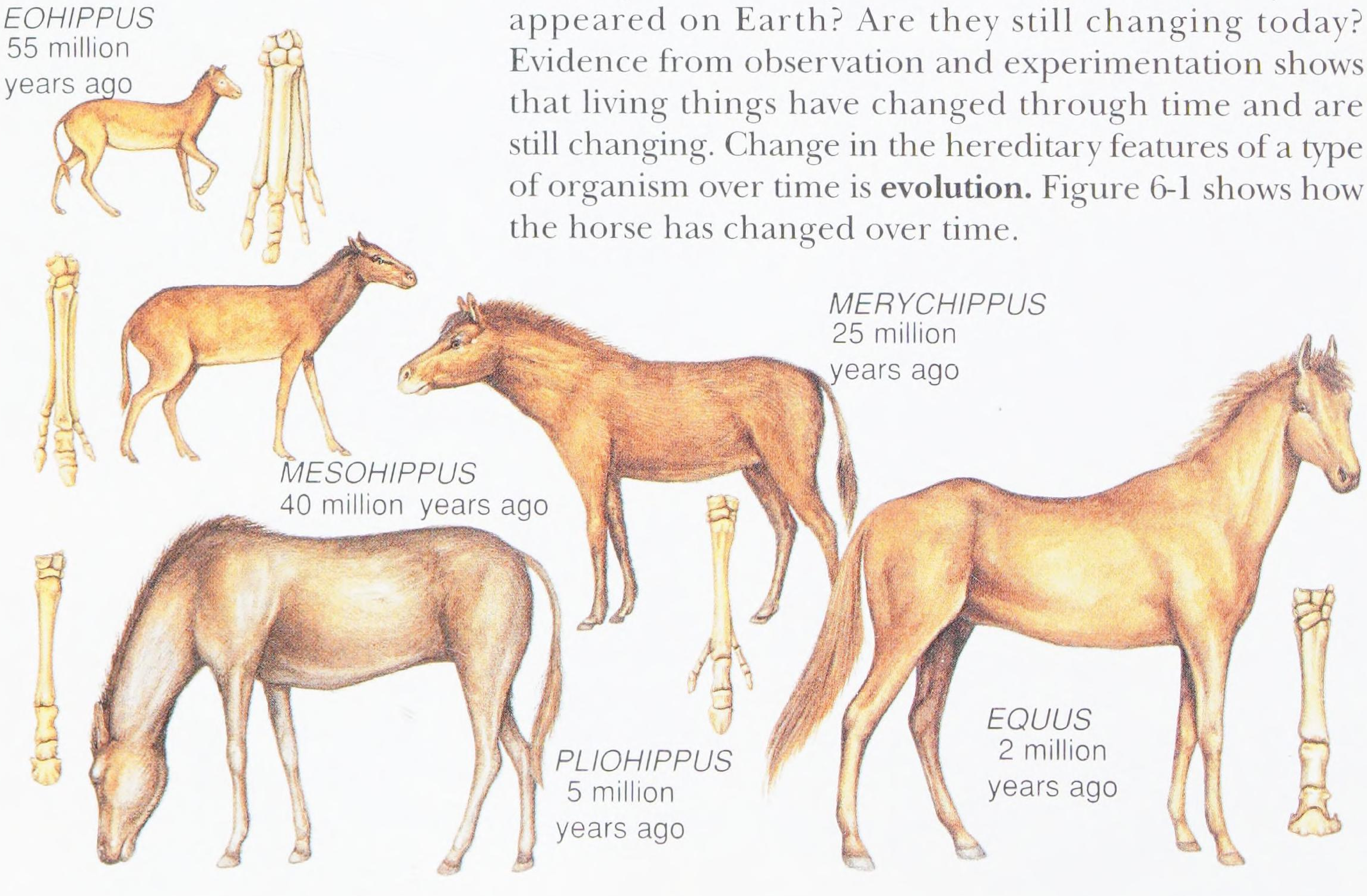
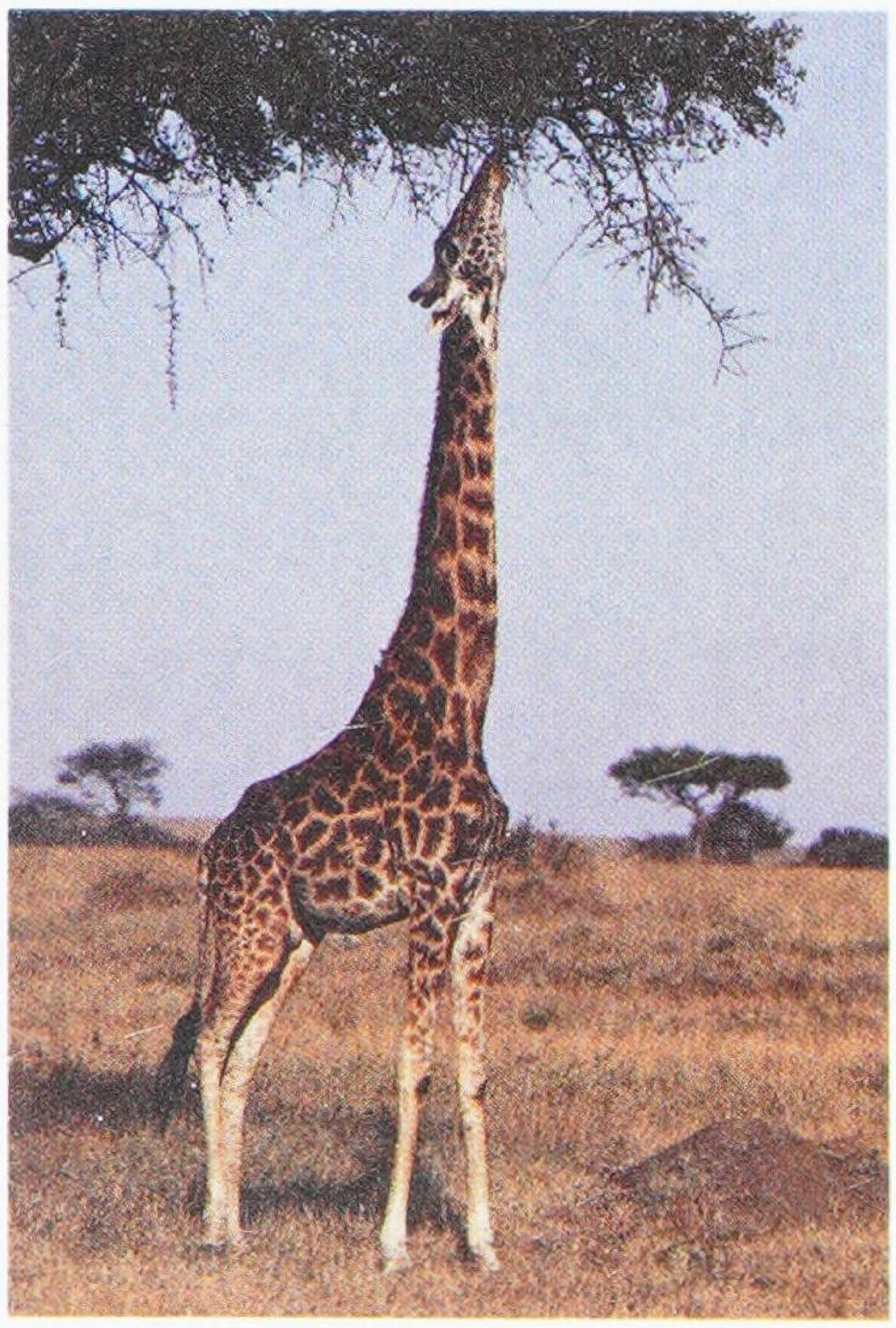

EOHIPPUS
55 million years ago
MESOHIPPUS
40 million years ago
MERYCHIPPUS
25 million years ago
PLIOHIPPUS
5 million years ago
EQUUS
2 million years ago

Figure 6-2. It takes years of practice and lessons for most people to acquire the ability to play an instrument well. However, the fact that you play well does not guarantee that the children you will have will play the piano well.

In 1809, Jean Baptiste de Lamarck, a French scientist, proposed one of the first theories to explain how species evolve or change. Lamarck hypothesized that species evolve by keeping traits that their parents developed during their life. Characteristics that were not used were lost from the species. According to Larmarck, if one of your parents was a bodybuilder and had large muscles, then you would be born with large muscles. Lamarck's theory of evolution is often called the theory of acquired characteristics.

When you study genetics, you learn that genes on chromosomes control the inheritance of traits. The traits you develop from your life-style, such as strong muscles from bodybuilding, are not inherited. After scientists collected large amounts of data on the inheritance of characteristics, Lamarck's theory wasn't accepted. The data showed that characteristics an organism develops during its life aren't passed on to its offspring.

Figure 6-3. According to Lamarck, the necks of giraffes became longer when they stretched to reach high branches, and this acquired trait was passed on to their offspring. However, long necks on giraffes are an adaptation.



Evolution by Natural Selection

In the mid-1800s, Charles Darwin developed the theory of evolution still accepted today. At the age of 22, Darwin, after trying several other careers, became the ship's naturalist aboard the *HMS Beagle.* The *Beagle* was on a trip to survey the east and west coasts of South America. The ship sailed from England in December 1831. Darwin was responsible for recording information about all the plants and animals he observed during the journey.

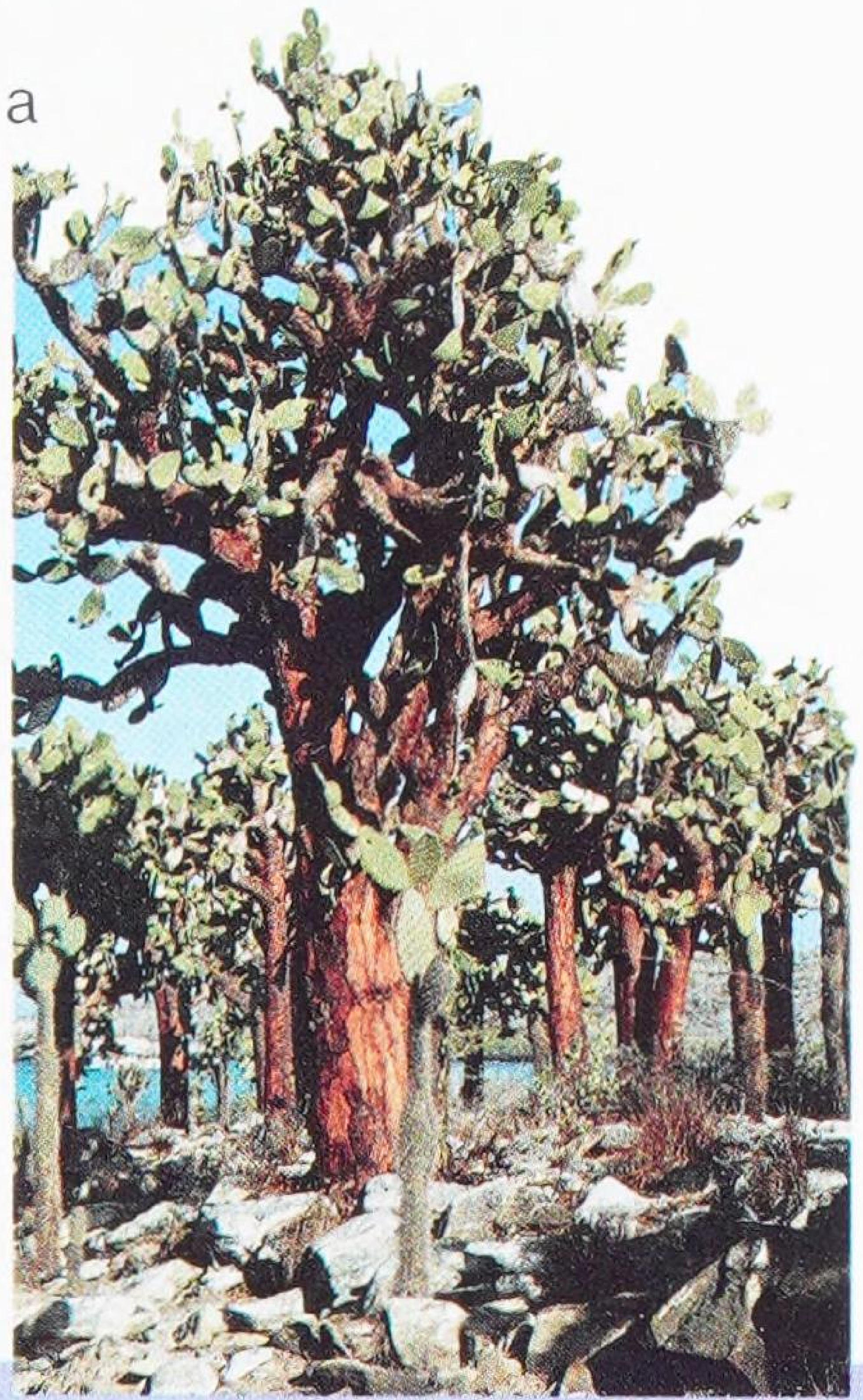
Darwin collected many plants, animals, and fossils. He was amazed by the unique plants and animals he found in the Galapagos Islands. The Galapagos Islands are located off the coast of Ecuador in South America. He observed giant cactus trees, 14 species of very similar finches, and huge land tortoises. Darwin was very interested in the finches. He wondered how so many different, but closely related, species of finches could live in areas so near each other.

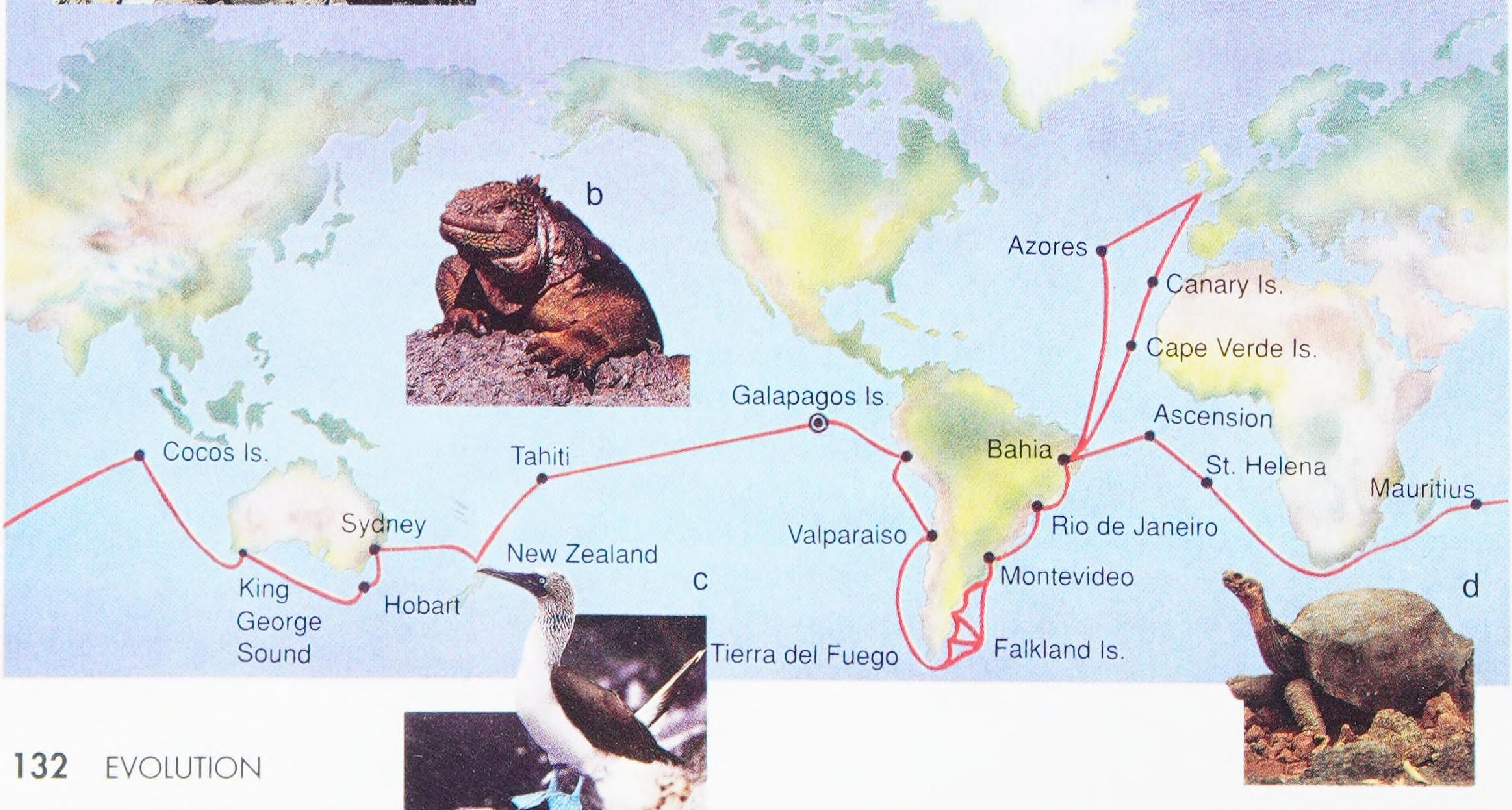
For 20 years after the voyage Darwin continued studying his collections. He thought about his observations and conducted further studies. He collected evidence of variations among species by breeding pigeons for racing. He also studied breeds of dogs, and other animals and varieties of flowers. Darwin knew that people used artificial selection in breeding plants and animals. They chose parents that had traits they wanted in the offspring.

Darwin concluded from his research that individuals with traits most favorable for a specific environment survived and passed on these traits to their offspring. This is the theory of **natural selection.** The factors Darwin identified that govern natural selection are:

1. Organisms produce more offspring than can survive.
2. Variations are found among individuals of a species.
3. Some variations enable members of a population to survive and reproduce better than others.
4. Over time, offspring of individuals with helpful variations make up more and more of a population.

Figure 6-4. A map of Darwin's voyage, and some of the unique organisms he found in the Galapagos Islands: (a) a tree cactus, (b) marine iguana, (c) the blue-footed booby, and (d) a Hood Island saddleback tortoise




b
Azores
Canary Is.
Cape Verde Is.
Galapagos Is.
Ascension
Bahia
St. Helena
Mauritius
Cocos Is.
Tahiti
Sydney
Rio de Janeiro
Valparaiso
New Zealand
King George Sound
Hobart
c
Montevideo
d
Tierra del Fuego
Falkland Is.

PROBLEM SOLVING

Why Isn't Earth Covered with Pumpkins and Pike?

Assume that there are 70 seeds in one pumpkin and that this is the typical number for the species. The 70 seeds are planted and each seed grows into a plant that produces two pumpkins. The first year 70 seeds are planted. The number of seeds produced in three years can be calculated by multiplying the number of seeds times two pumpkins for each plant times 70 seeds in each pumpkin:

Year 1: 70 x 2 x 70 = 9800
Year 2: 9800 x 2 x 70 = 1 372 000
Year 3: 1 372 000 x 2 x 70
= 192 080 000 seeds

The largest possible number of offspring produced by one individual is known as the biotic potential of a species.

If the ovaries of a pike contain 42 000 eggs, all the eggs are fertilized and hatched, all the young survive to reproduce, and one-half of the young are females, how many pike would there be after two more generations?

Think Critically: Why is the maximum rate of biotic potential never reached?

Natural selection results in organisms with traits best suited to their environments. This theory has also been called "survival of the fittest."

Darwin wrote a book describing his theory of evolution by natural selection. His book *On the Origin of Species by Means of Natural Selection* was published in 1859. Although minor changes have been made to Darwin's theory as new information has been gathered, his theory is one of the most important concepts in the study of life science.

In Your JOURNAL

In your Journal, describe how the work of Alfred Wallace interacted with that of Charles Darwin.

Adaptation and Variation

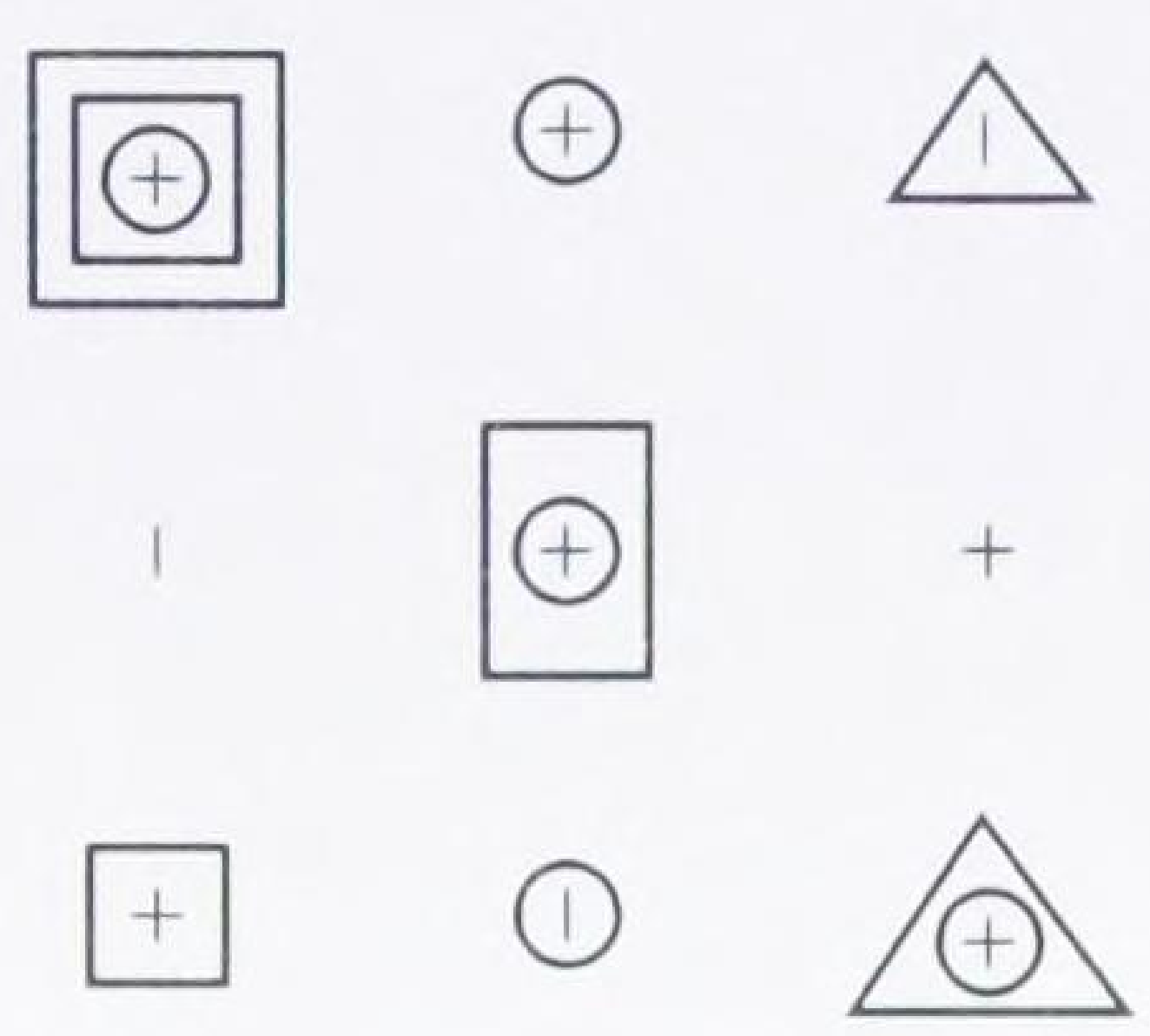
What is a variation?

One of the points in Darwin's theory of evolution is that variations are found among individuals of a species. What are variations? A **variation** is an appearance of an inherited trait that makes an individual different from other members of the same species. Variations can be small, such as differences in the number of petals of a

MINI-Lab

How does evolution occur?

Below are diagrams representing different species that came from the same ancestor. Determine which is the ancestor and then put the species in order, from simplest to most complex. Use one change in structure at a time. Each structural change is a variation and a new species forms. How does this help illustrate how evolution occurs?

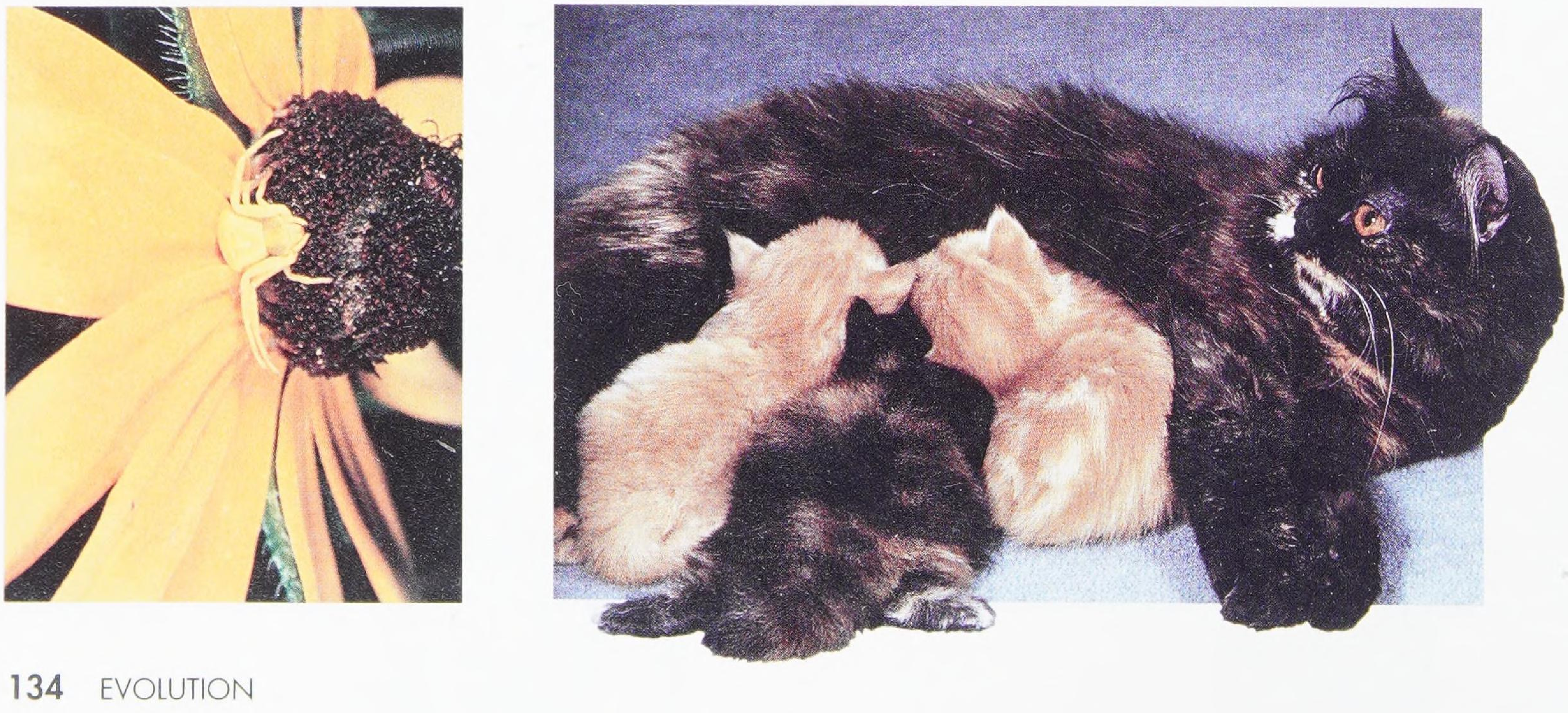


flower, or large, such as an albino deer or a fruit without seeds. Variations are important in populations of organisms. A **population** is a group of organisms of one species that live in an area. If enough variations spread through a population as it produces new offspring, a new species may evolve from the existing species. Evolution of a new species usually takes many generations.

Some variations are more helpful than others. An adaptation is any variation that makes an organism better suited to its environment. The variations that result in adaptation can be in an organism's color, shape, behavior, or chemical makeup. Camouflage is a protective adaptation that lets an organism blend into its environment. An organism whose color or shape provides camouflage is more likely to survive and reproduce. Organisms that can't be easily seen are more likely to survive and reproduce. These types of variations result from mutations, changes in an organism's DNA. Mutations are the source of variation among organisms.

Several other factors bring about evolution. The movement of individuals into or out of a population brings in new genes and variations. Have you ever had an exchange student come to your school? The student probably brought new ideas, maybe a new style of dress, and even a new language. When new individuals come into an existing population, they can bring in new genes and variations in much the same way. The isolation of some individuals from others by geography and changes in climate can also result in evolutionary change. Each of these factors affects how fast evolution occurs.

Figure 6-5. Variation causes some organisms to blend into their environment. Variations among kittens often occur in the same litter.



How Fast Does Evolution Occur?

How fast does evolution occur? Scientists are debating that question. Most scientists hypothesize that evolution occurs very slowly, perhaps taking tens or hundreds of millions of years. Other scientists hypothesize that evolution may occur very quickly, perhaps in a million years.

Darwin hypothesized that the rate of evolution was steady, slow, and continuous. The model that describes evolution as a slow change of one species to another new species is known as **gradualism.** In this theory there should be intermediate forms of all species.

Another model, the **punctuated equilibrium** model, states that rapid evolution of species comes about by the mutation of a few genes. This is a steplike pattern of evolution. These mutations produce large changes in body form in a short period of time. The fossil record gives examples of this type of evolution.

What is the rate of evolution? As you study the evidence for evolution, you will see that evidence supports a combination of the two models.

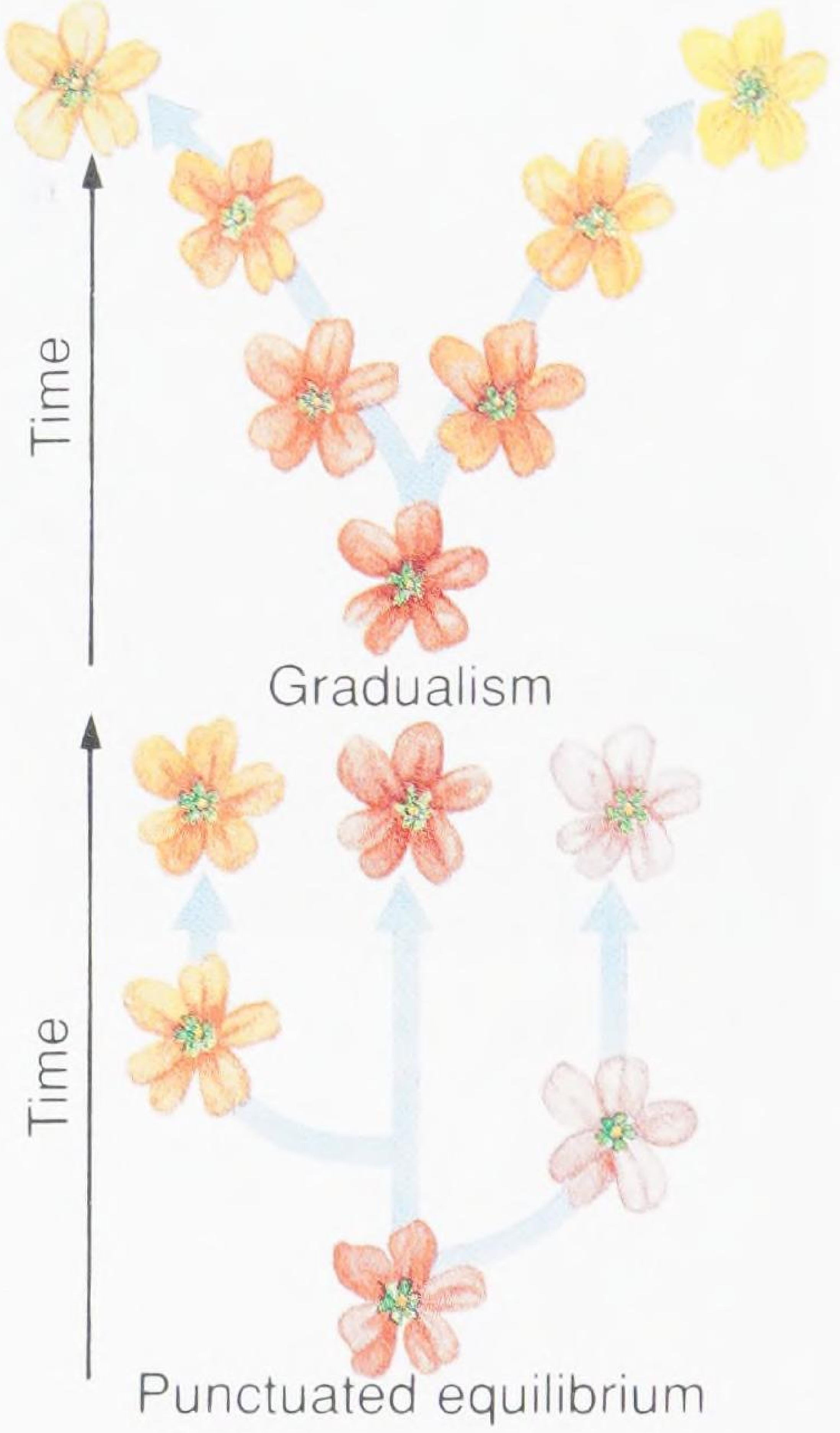


Figure 6-6. Evolution can occur very slowly, as in gradualism, or very rapidly, as in punctuated equilibrium.

SECTION REVIEW

1. Compare Lamarck's theory of evolution with Darwin's.
2. How are variations important in a population?
3. Explain how the gradualism model of evolution differs from the punctuated equilibrium model.
4. **Apply:** Which of the following variations would be beneficial to an animal living in the Arctic; thick fur, large size, large ears? Why?
5. **Connect to Earth Science:** What geologic feature do the Galapagos, Hawaiian and Canary Islands have in common?

Classifying

Skill Builder

Classify the following variations as being in an organism's shape, color, chemical makeup, or behavior.

1. Two species mate and don't produce offspring.
2. One species has large forelimbs and another species has short forelimbs.
3. Two species of birds build nests in different places.

If you need help, refer to Classifying in the **Skill Handbook** on page 680.

6-2 Evidence for Evolution

New Science Words

fossils
sedimentary rock
relative dating
radioactive elements
homologous
vestigial structure
embryology

Objectives

- Describe the importance of fossils as evidence of evolution.
- Explain how relative and radioactive dating are used to date the fossil record.
- Give examples of five types of evidence for evolution.

Fossil Evidence

On a hot day in July 1975, in North Central Texas, a young couple was strolling along the breezy shores of Lake Lavon. The couple came across some odd-looking rocks projecting from the muddy shore. They noticed the rocks seemed different from the surrounding limestone rocks. They took a few of the rocks to Dr. Harold Laughlin, a local scientist specializing in reptiles and amphibians. Dr. Laughlin recognized the rocks as pieces of the skull of a fossil mosasaur (MA sah sawr), an extinct lizard that lived in salt water.

Figure 6-7. Uncovering fossils requires careful work.

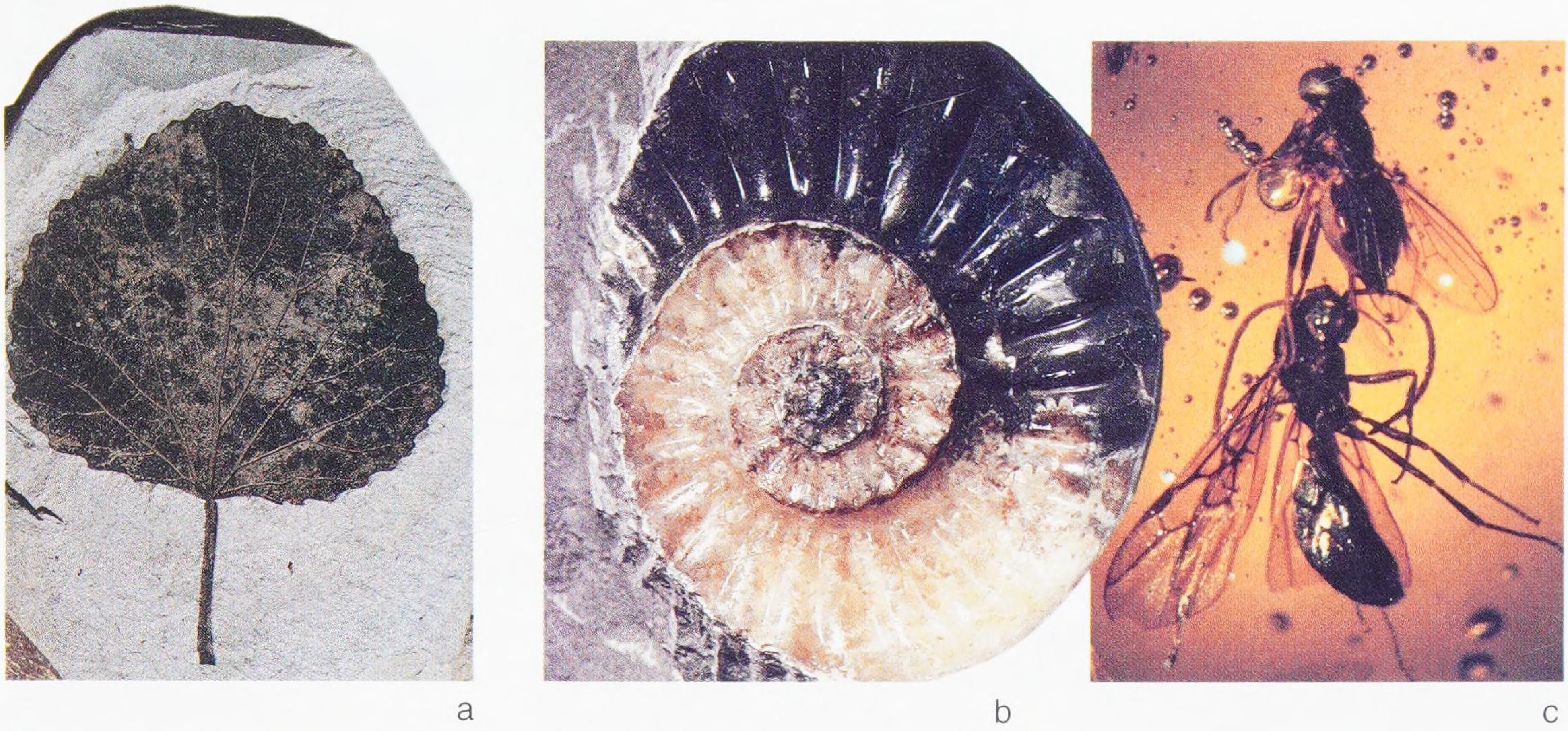


Figure 6-8. Three examples of fossils are shown: (a) an imprint made by a leaf, (b) a cast of an ancient mollusk, and (c) an insect caught in plant resin.

Dr. Laughlin contacted Professor Slaughter, a scientist who studies fossils, at Southern Methodist University. With the help of students, Professor Slaughter and Dr. Laughlin returned to the site and carefully dug up the rest of the fossil mosasaur. It took one of Slaughter's graduate students almost a year to study, preserve, and reassemble the 1.75 meter skull of the 15-meter-long fossil mosasaur. This find provides evidence that about 120 million years ago, the North Texas area—now more than 500 kilometers from the Gulf of Mexico—was covered by a shallow sea.

The most abundant evidence for evolution comes from fossils like those found on the shore of Lake Lavon in Texas. **Fossils** are any remains of life from an earlier time. Examples of fossils include:

1. the imprint of a leaf, animal, or feather in rock;
2. a cast made of minerals that filled in the hollows of an animal track or mollusk shell;
3. a piece of wood or bone replaced by minerals;
4. an animal or plant frozen in ice; and
5. an insect or reptile trapped in plant resin.

Sedimentary rock contains most fossils. **Sedimentary rock** is a rock type formed by mud, sand, or other fine particles that settle out of a liquid. Limestone, sandstone, and shale are all examples of sedimentary rock. Fossils are found more often in limestone than in any other kind of sedimentary rock.

MINI-Lab

How are fossils made?

Pour a small amount of plaster of Paris into a small paper cup or other small paper container. Press a small object such as a seashell, key, or leaf into the mixture. Carefully lift the object out of the container. Let the plaster dry for one to two days. Tear the paper away from the container. What type of fossil have you made? *Infer* whether a plant or an animal would be more likely to make this type of fossil. Explain your choice.

The Fossil Record

You learned that the mosasaur fossil found in Texas was 120 million years old. How was that date obtained? Scientists have divided Earth's history into eras and periods. These divisions make up the geologic time scale as shown in Table 6-1. Unique rock layers and fossils give information about the geology, weather, and life forms of each time period. There are two basic methods for reading the record of past life. When these methods are used together, accurate estimates of the ages of certain rocks and fossils are made.

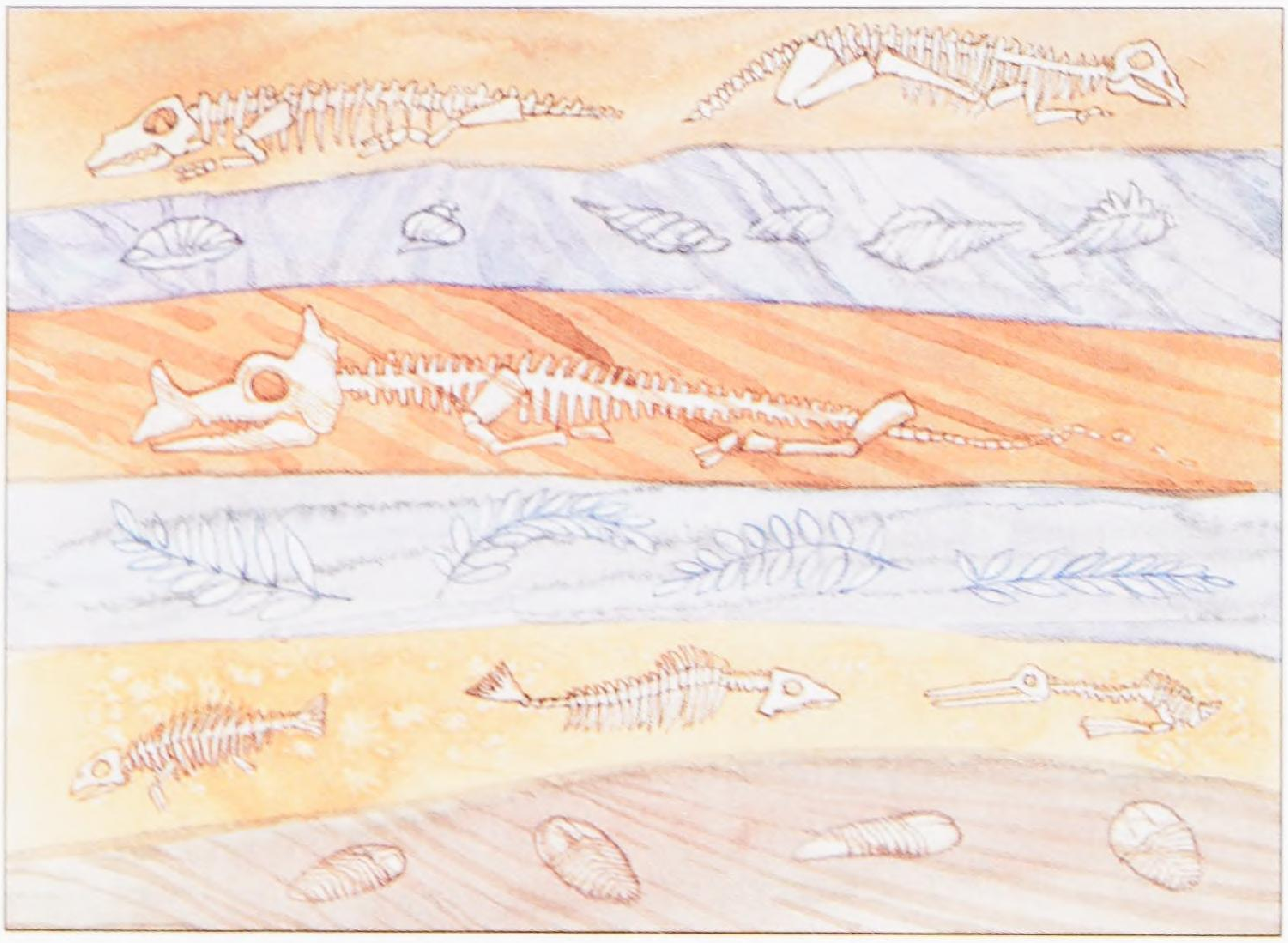


Figure 6-9. Fossils found in lower layers of sedimentary rock are usually older than fossils in upper layers.

One method often used to determine the approximate age of a rock layer, or fossils within the layer, is to look at where the particular rock layer is. In undisturbed areas, older rock layers lie below successively younger rock layers. Fossils found in the lower layers of rock are older than those in upper layers. This method of dating fossils is known as **relative dating.** Relative dating can only estimate the age of a fossil.

How are fossils dated using radioactive elements?

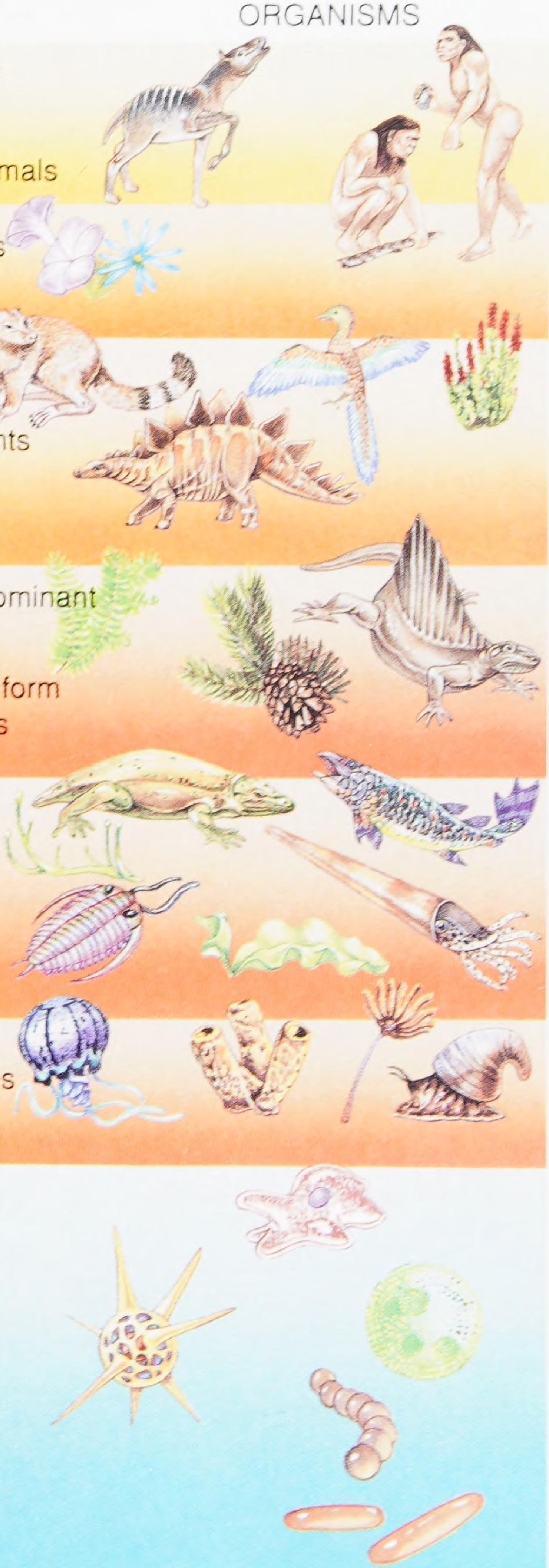
A method used to give a more accurate age to a rock layer or fossil is radioactive dating using radioactive elements. **Radioactive elements** are elements whose atoms give off radiation, a form of atomic energy. Uranium and a radioactive form of carbon are used in radioactive dating. Radioactive elements change to more stable products as they give off radiation. The radiation is given off at a constant rate, and the rate is different for each element. Scientists can measure how much of a radioactive element has changed. They can accurately determine the age of the rock by comparing the amount of stable product with the amount of radioactive element still present. For example, the radioactive element uranium changes to lead as it ages. Scientists can determine how old a fossil in a rock sample is by measuring the amounts of uranium and lead in the sample. The more lead there is, the older the fossil.

Table 6-1

GEOLOGIC TIME SCALE

ERA	PERIOD	MILLION YEARS AGO	MAJOR EVOLUTIONARY EVENTS
Cenozoic	Quaternary	5	Humans evolve
	Tertiary	65	First placental mammals
Mesozoic	Cretaceous	144	Flowering plants dominant
	Jurassic	213	First birds First mammals First flowering plants
	Triassic	248	First dinosaurs
Paleozoic	Permian	286	Cone-bearing plants dominant
	Carboniferous	320 360	First reptiles Great coal deposits form First seed plants
	Devonian	408	First Amphibians
	Silurian	438	First land plants First jawed fish
	Ordovician	505	Algae dominant First vertebrates
	Cambrian	590	Simple invertebrates
Precambrian		3500	Life diversifies Eukaryotes Prokaryotes Life evolves

REPRESENTATIVE ORGANISMS



TECHNOLOGY

An Ostrich Egg Timer

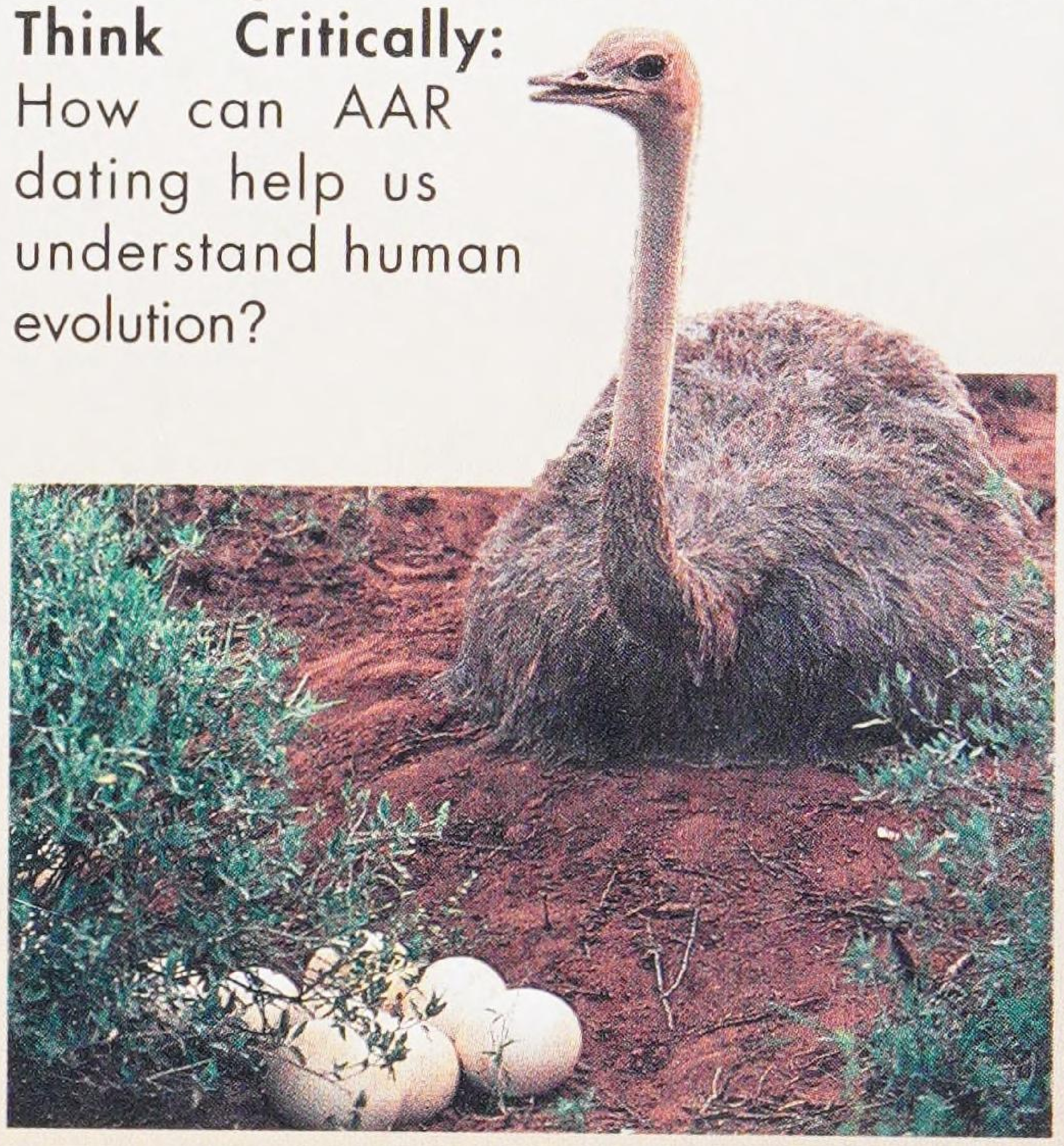
A dating technique called amino acid racemization (AAR), used to date the age of fossil objects, may turn ordinary eggshells into geologic clocks.

AAR uses amino acids left in materials produced by living things, to figure out how old the materials are. Over time, amino acids change into a slightly different form of their original form. By measuring the ratio of the original amino acids to the changed amino acids in an eggshell, the age of the shell can be determined. The technique works better in cold climates. In warm climates the rate of amino acid change is affected by temperature and by moisture.

Scientists are excited by AAR because it can be used to date objects that can't be dated by radioactive dating, such as eggshells, bits of rock, and tooth enamel. Ostrich eggshells are very common in many archeological sites. Early humans ate the eggs, and then used the shells as water containers. Using AAR to date the eggshells helps scientists determine the age of the site.

AAR is an important technique because it allows scientists to date back 200 000 years at warm-weather sites, and one million years at cold-weather sites. Current radioactive carbon dating methods can't date back this far.

Think Critically: How can AAR dating help us understand human evolution?



Science and MATH

Using Table 6-1 on page 139, *estimate* the number of years from the time life evolved to the time when the first land plants arose.

Fossils are a record of organisms that lived in the past. But the fossil record is incomplete, much like a book with some pages missing. Because every living thing doesn't or can't become fossilized, the record will never be complete. By looking at fossils, scientists have determined that many simpler forms of life existed earlier in Earth's history, and more complex forms of life appeared later. The oldest fossil bacteria appeared 3.8 billion years ago. Simple plants did not appear until the Ordovician period, about 440 million years ago. The first mammals and birds did not appear until the Jurassic period, about 190 million years ago. The fossil record gives scientists convincing evidence that living things evolved. There are still other types of evidence that support the theory of evolution.

Other Evidence for Evolution

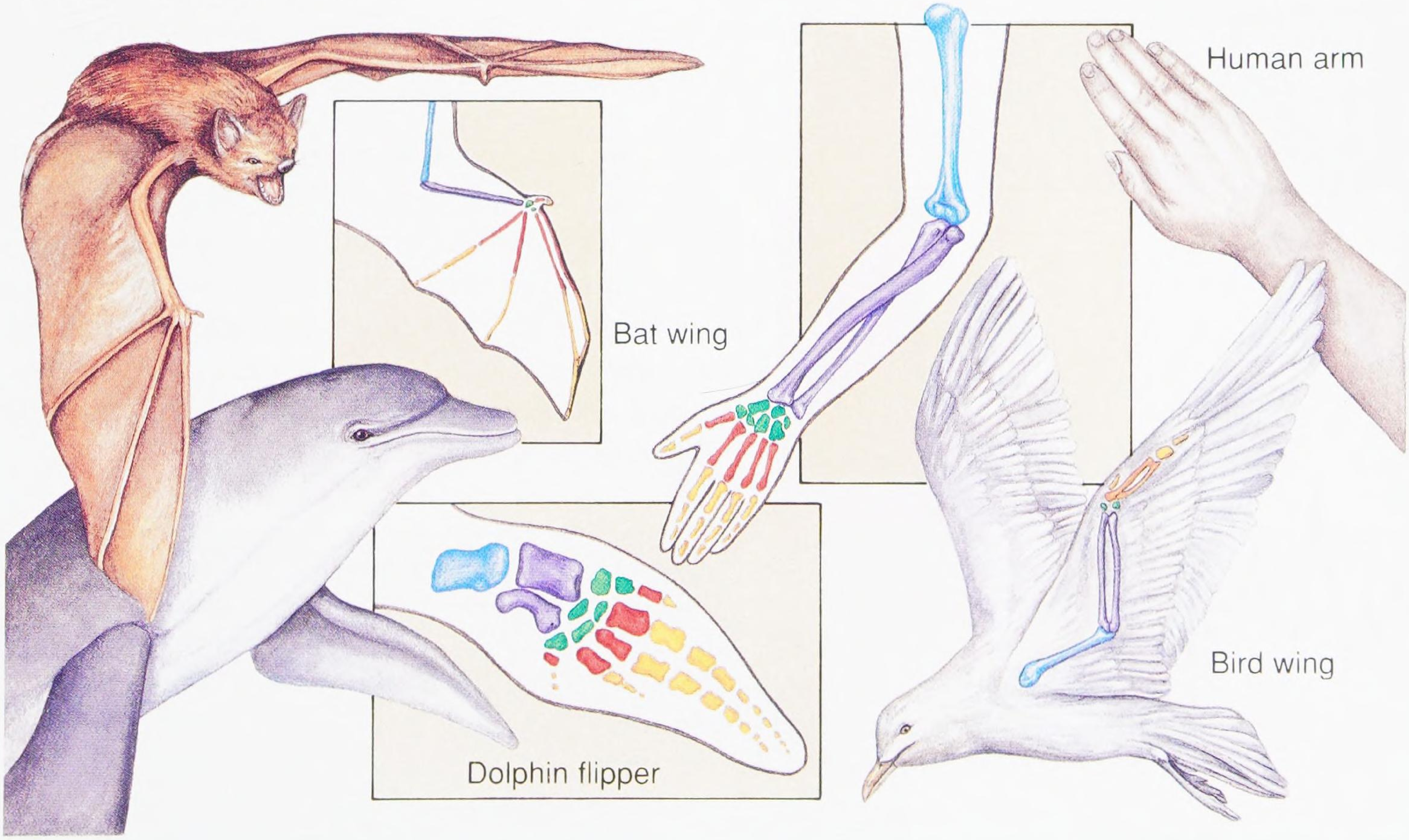
Besides fossils, what other evidence is there for evolution? Scientists have found more evidence by looking at similarities in the chemical makeup, the development, and the structure among organisms. You know that the functions of your arm, a dolphin's flipper, a bat's wing, and a bird's wing are all very different. Yet, as you can see in Figure 6-10, they are all made up of the same bones. Each has about the same number of bones, muscles, and blood vessels. Each of these limbs developed from similar tissues in the embryo. Body parts that are similar in origin and structure are called **homologous.** Homologous structures give evidence that two or more species share common ancestors.

Vestigial structures also give evidence for evolution. A **vestigial structure** is a body part that is reduced in size and doesn't seem to have a function. Examples of vestigial organs in humans are the appendix and the muscles that move the ear. Scientists think vestigial structures are parts that once functioned in an ancestor.

Connect to... Chemistry

If two species of organisms have a similar type of protein, what are the chances that they share a common ancestor?

Figure 6-10. A bird wing, bat wing, dolphin flipper, and human arm are homologous. Each has about the same number of bones, muscles, and blood vessels.



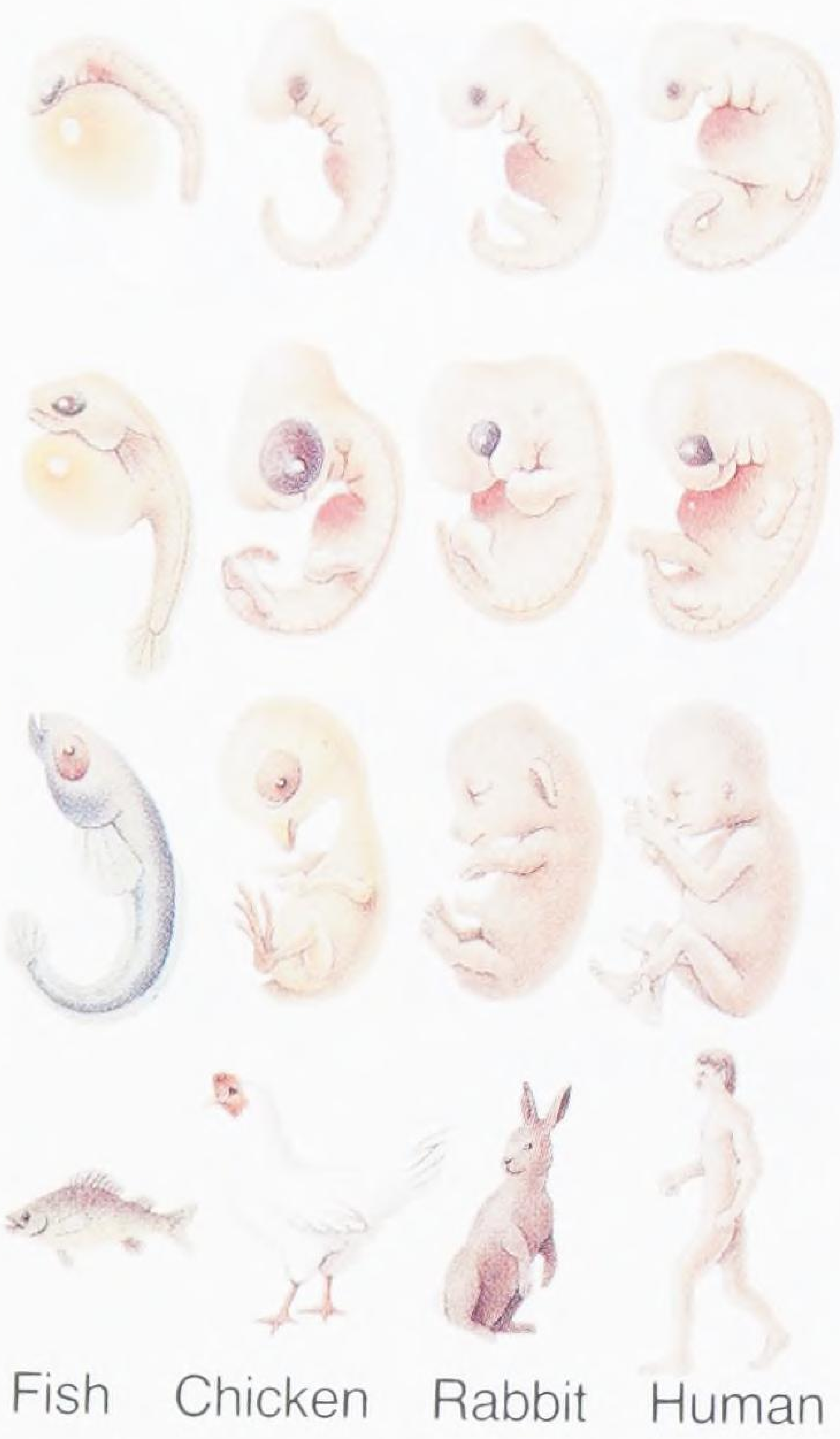


Figure 6-11. Similarities in the embryos of fish, chickens, rabbits, and humans show evidence of evolution.

The study of the development of embryos is called **embryology.** An embryo is an organism in its earliest stages of development. Compare the embryos of the organisms in Figure 6-11. Do you see similarities? In the early stages of development, the embryos of fish, reptiles, birds, and mammals have a tail and gills or gill slits. Fish keep their gills, but the other organisms lose them as their development continues. In humans, the tail disappears, but fish, birds, and lizards keep theirs. These similarities suggest an evolutionary relationship among all vertebrate species. This supports evidence from the fossil record that shows aquatic, gill-breathing organisms came before air-breathing land vertebrates.

DNA is the molecule that controls heredity. Scientists can also determine whether or not organisms are closely related by comparing their DNA. Organisms that are close relatives share more similarities in DNA with each other than with distant relatives. For example, by studying DNA, scientists have determined that dogs are the closest relatives of bears. You would probably not be surprised that gorillas and chimpanzees also have DNA that is very similar.

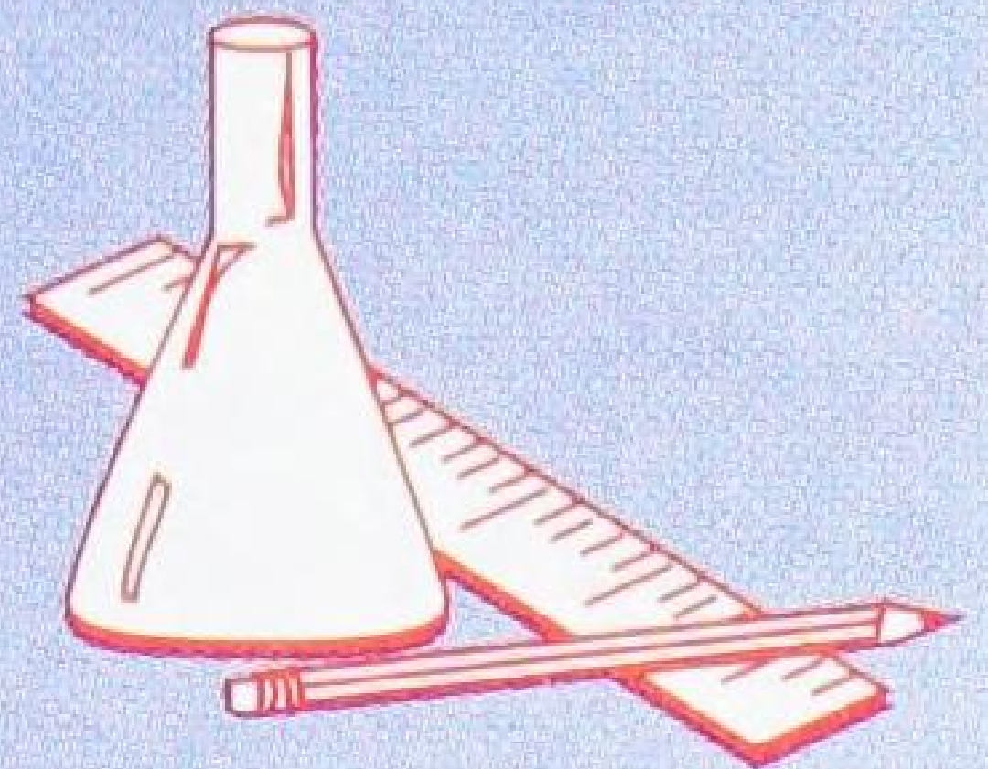
SECTION REVIEW

1. How do fossils provide evidence for evolution?
2. How is radioactive dating used to interpret the fossil record?
3. List five examples of evidence that support the theory of evolution.
4. **Apply:** Fossil leaves are found in the top layer, fossils of shells are found in the bottom layer, and fish bones are in the middle layer of three undisturbed beds of rock. List the fossil types from oldest to youngest.
5. **Connect to Earth Science:** What type of rock are the fossils in question 4 found in?

Skill Builder

Making and Using Tables

Use Table 6-1, The Geologic Time Scale, to answer the following questions. During which periods did the first mammals and flowering plants appear? Which was the longest period of the Paleozoic era? If you need help, refer to Making and Using Tables in the **Skill Handbook** on page 690.



ACTIVITY 6-1

A Radioactive Dating Model

Problem: *How can a radioactive element be used to determine a fossil's age?*

Materials

- 100 pennies
- cardboard box with lid
- graph paper
- pencil

Procedure

1. A rock or fossil may be dated by measuring the relative amount of a stable element with its radioactive parent element. As the rock ages, the amount of radioactive element become less and the amount of stable element increases. Examine the graph below to see the decrease of a radioactive element over time.
2. Make a data table like the one shown.
3. Put 100 pennies face up in the cardboard box and replace the lid.
4. Shake the coins in the box for 10 seconds.
5. Take off the lid and take out all coins that are face down.
6. Record the number of coins that you take out.
7. Repeat Steps 4 through 6 until all the coins have been removed.

Data and Observations

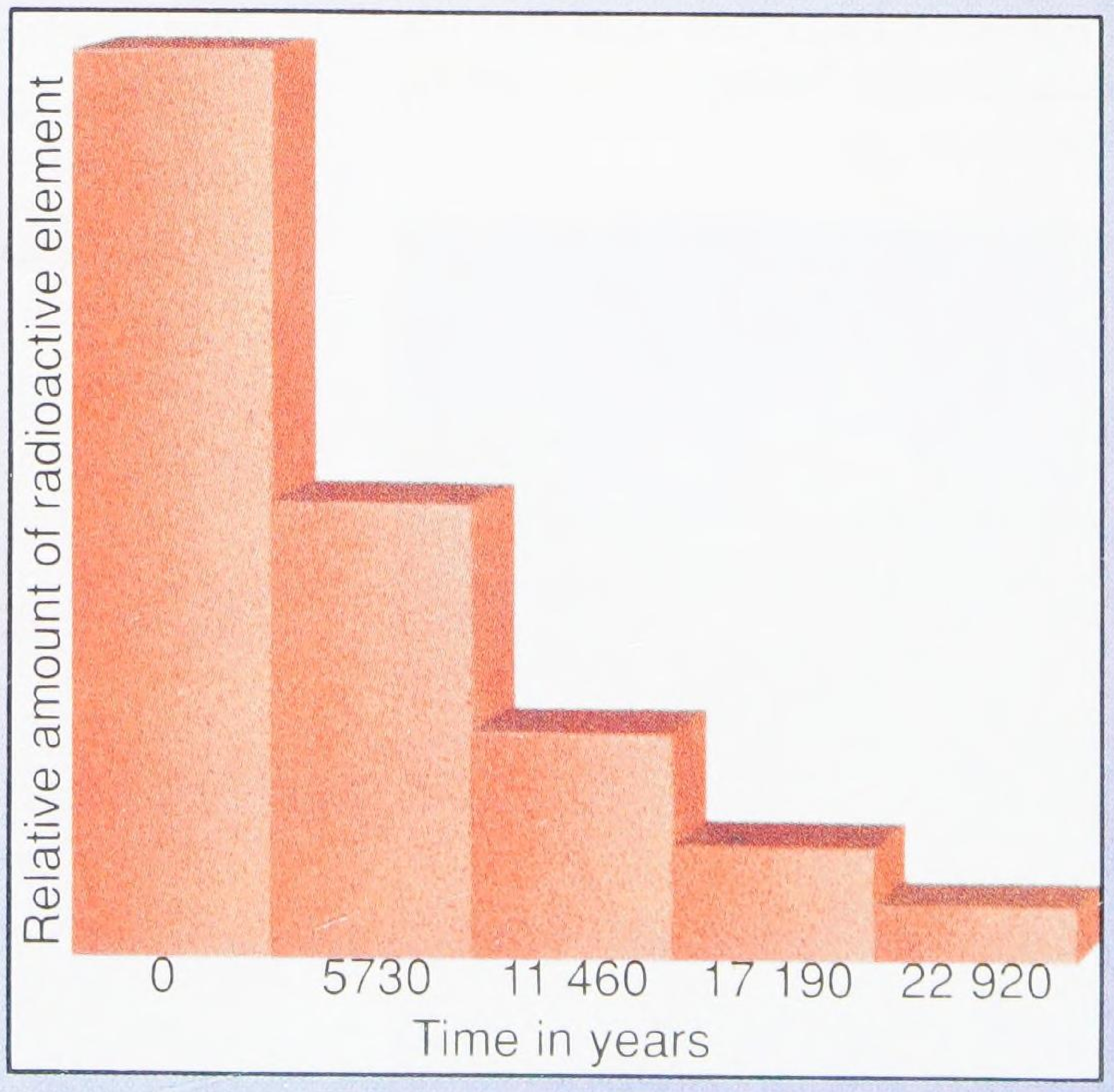
Trial #	0	1	2	3	4	5	6	7	8
Coins Left	100								
# Removed	0								

Analyze

1. What happens to the number of coins remaining after each trial?
2. Construct a graph of your results. Plot the number of coins remaining face up on the *y*-axis, and plot the trials on the *x*-axis. How does your graph compare with the graph below?
3. How does shaking the box represent the energy given off by radioactive elements when they become stable?

Conclude and Apply

4. How is this model similar to the decay of a radioactive element?
5. How is this model unlike the decay of a radioactive element?
6. Why do you think radioactive dating is considered more accurate than dates calculated from fossil beds?
7. Why are different radioactive elements used to date rocks and fossils?



SCIENCE & SOCIETY

6-3 Plant and Animal Extinction

New Science Words

extinction
endangered species

Objectives

- Define extinction and identify some causes of extinction.
- Name two ways in which endangered species may be saved from extinction.

Connect to... Earth Science

Evidence that extinction is a natural event is found in the fossil record. Large scale extinction events, such as extinction of the dinosaurs, have taken place in the past. Find out when extinction of the dinosaurs took place.

Causes of Extinction

By the time you finish reading this paragraph, one more animal or plant species may have joined the thousands that have become extinct. Some scientists estimate that one-fourth of all animal and plant species alive in the world today will be extinct in only 25 years! What's going on?

Extinction, the dying out of a species, is a natural event. Extinction occurs naturally because the environment is always changing. To survive, each species must adapt to it. In nature, only those species that can best adapt to the changing environment will escape extinction. Through the slow process of natural selection, those species that are genetically unable to change or adapt as the environment changes are naturally removed.

The rate of extinction has increased greatly due to destruction of natural habitats by humans. Not only have humans destroyed many species of plants and animals, but we also have destroyed habitats and food supplies that organisms depend on. With no home or food supply, a species will eventually die.

Figure 6-12. Plant and animal habitats are being destroyed by development.

Ways to Prevent Extinction

How can extinction be prevented? One way is to preserve the remaining natural areas in which endangered plants and animals live. An **endangered species** is one whose numbers are so low that it is in danger of becoming extinct. By preserving areas that have not yet been destroyed, we can keep organisms in their natural homes and let them rebuild their populations. Organizations, such as the Nature Conservancy, are working hard to save what untouched natural areas remain.

What is an endangered species?

Another way to prevent extinction is to remove endangered animals from their natural habitats and breed them in captivity. After helping animals reproduce in a setting that provides food, shelter, and protection, researchers may then release them into the wild. Zoos have become very important in these types of programs.

Researchers are battling the extinction of Bengal tigers in this way. Only 3000 to 5000 of these tigers remain in the wild. This endangered species may be saved by a technique known as in vitro fertilization, joining an egg and sperm together in a test tube. An embryo results from the joining of an egg and sperm. Embryo transfer, the placing of the embryo in a female, then follows. If the procedure is successful, the embryo develops into a baby tiger. Zoos have been successful in breeding Bengal tigers by placing the embryo in a female Siberian tiger. Through surgery, the developed kittens were removed from the foster mother.

Figure 6-13. Bengal tigers are being bred in captivity to help save them from extinction.

It is hoped that in vitro fertilization can be used to help many other endangered animal species. By protecting the natural areas that are not yet destroyed and by breeding animals in captivity, preservationists are working to slow the current rate of extinction and preserve the species that remain.

SECTION REVIEW

1. Why is extinction not always a bad event?
2. Describe two ways to save endangered species.
3. **Connect to Earth Science:** Find out what hypotheses exist to explain extinction of the dinosaurs.

You Decide!

SCIENCE & SOCIETY

A lot of energy and money is put into programs that help us save endangered species from extinction. Are these species really worth our time and effort? Should we be concerned about saving an animal or plant that we'll never see?

6-4 Human Evolution

New Science Words

primates
hominids
Homo sapiens

Objectives

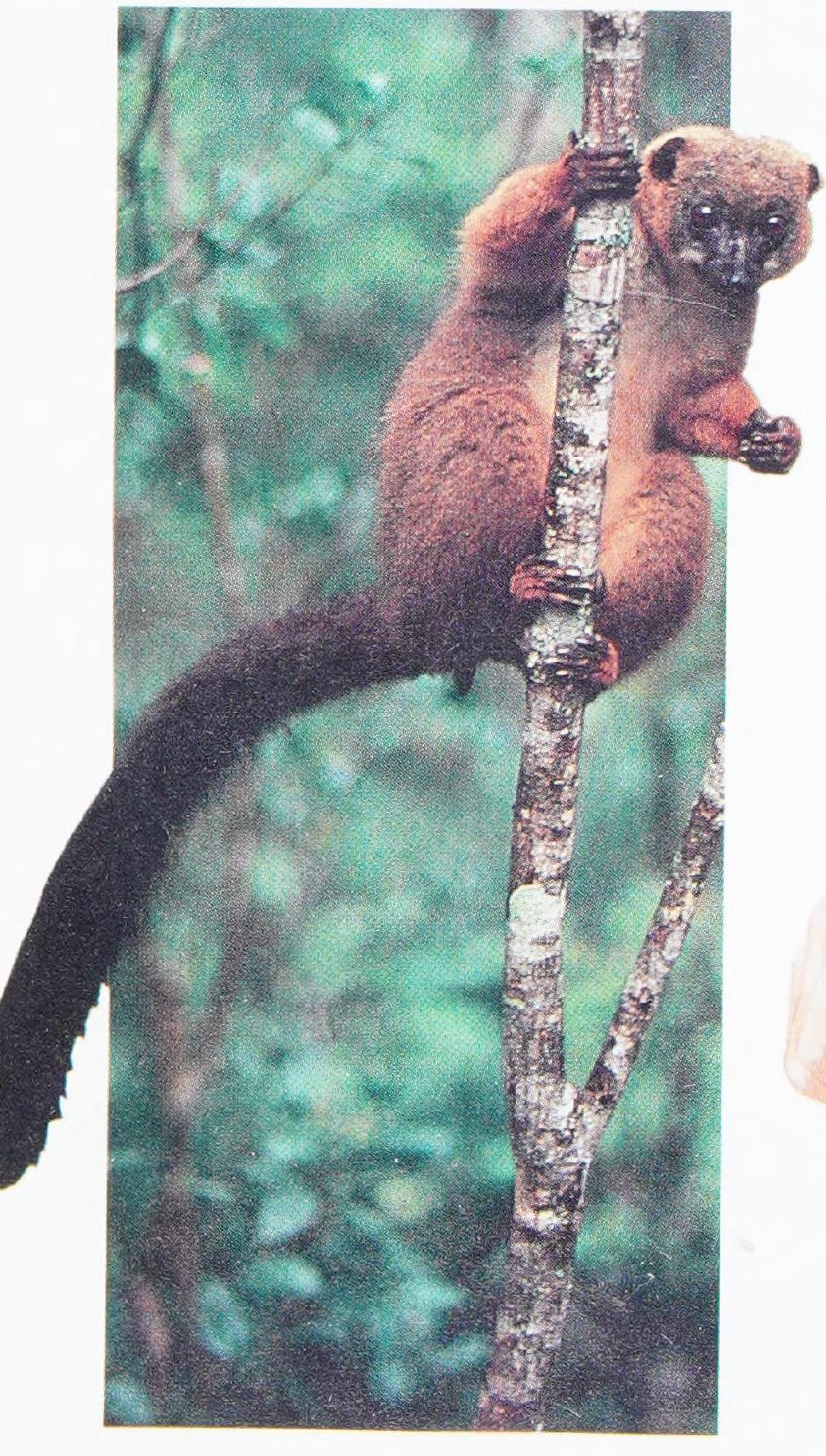
- Describe the evidence that monkeys, apes, and humans evolved from a common ancestor.
- Describe the ancestors of humans.
- Trace the evolutionary history of humans.

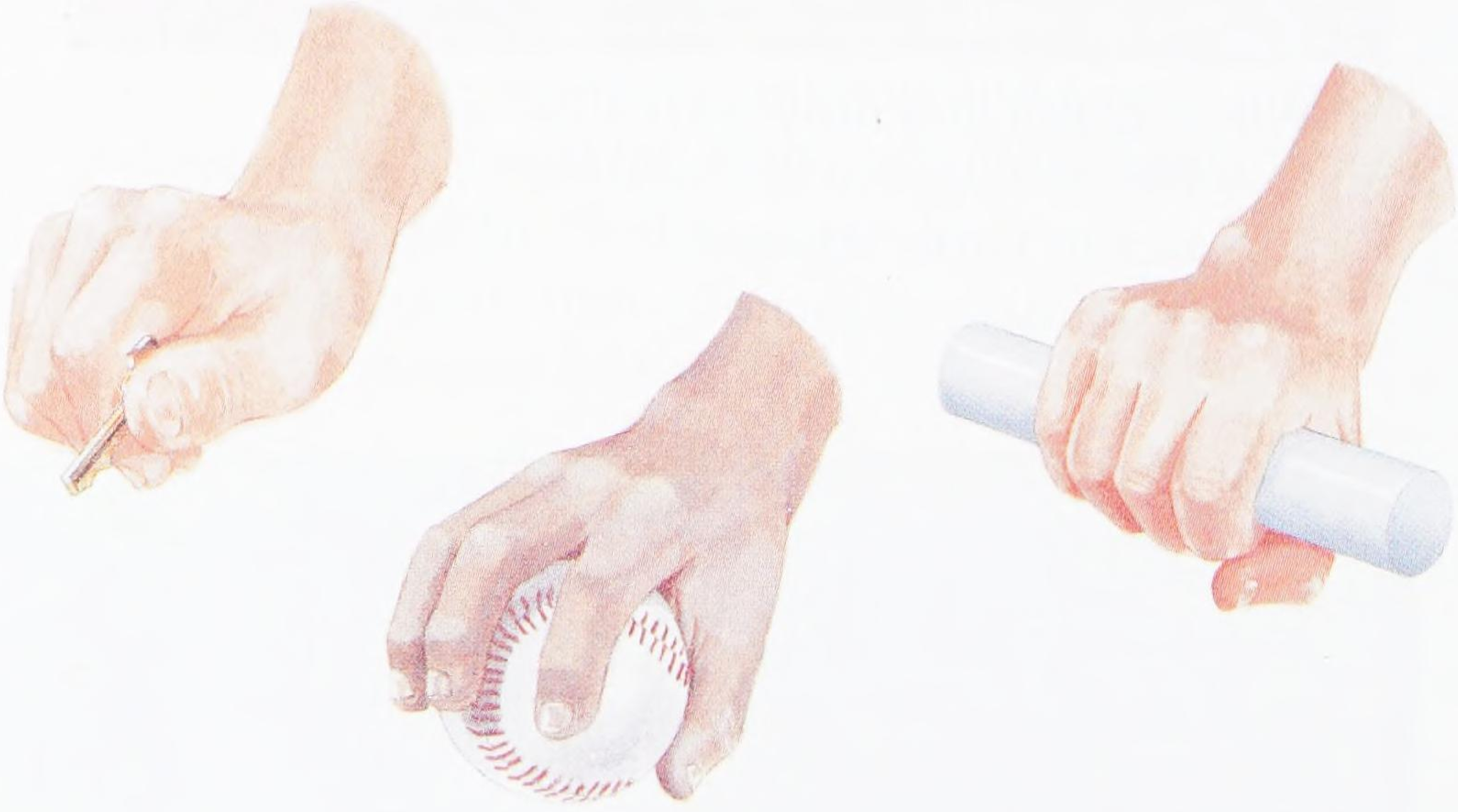
Primates

Monkeys, apes, and humans belong to the group of mammals called **primates.** The primates share several characteristics that led scientists to think all primates evolved from a common ancestor. All primates have opposable thumbs that allow them to reach out and bring food to the mouth. Having an opposable thumb allows you to cross your thumb across your palm and touch your fingers. Think of the problems you might have if you didn't have this type of thumb!

Another important primate characteristic is binocular vision. Binocular vision permits a primate to judge depth or distance with its eyes. All primates have flexible shoulders and rotating forelimbs. These allow tree-dwelling primates to swing easily from branch to branch, and allow you to swing on a jungle gym. Each of these characteristics provides evidence that the primates have common ancestry.

Figure 6-14. An opposable thumb allows tree-dwelling primates to hold onto branches. It also allows you to use your hand in many ways.





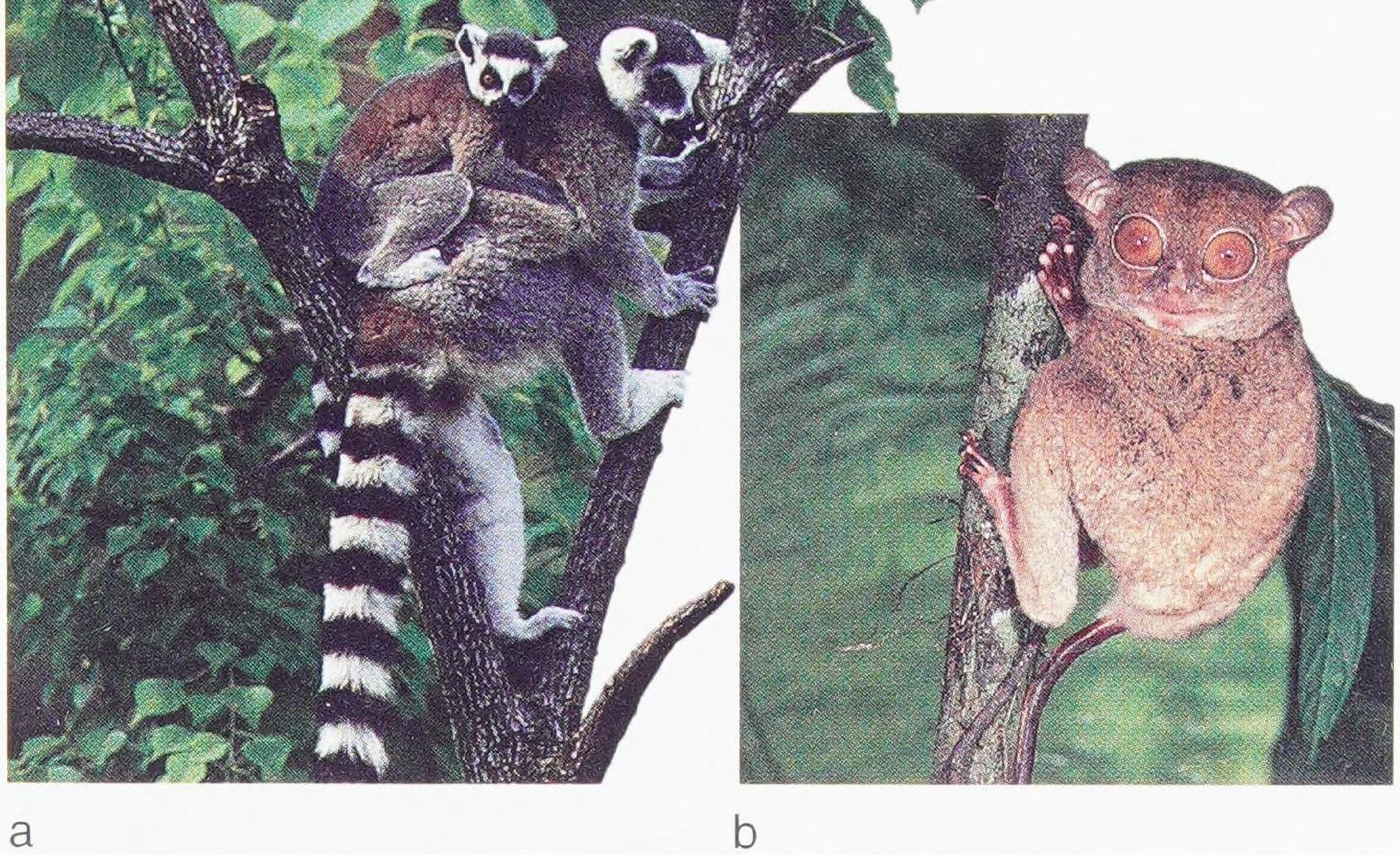


Figure 6-15. Lemurs (a) and tarsiers (b) belong to a subgroup of primates called the prosimians, which means "before apes."

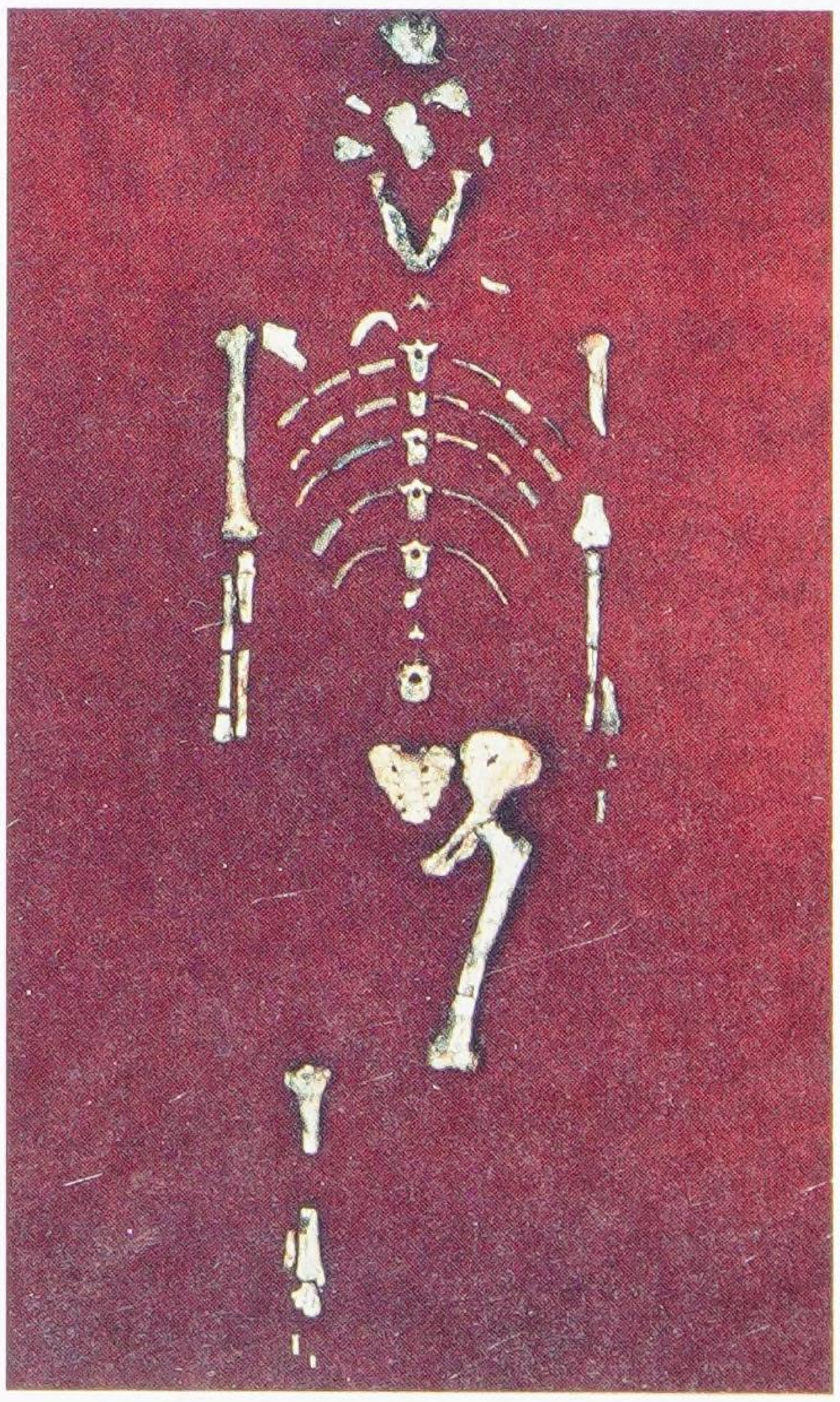
Genetic evidence also supports the view that monkeys, apes, and humans all evolved from a common ancestor. The DNA of chimpanzees, gorillas, and humans is very similar. In addition, primates share many of the same proteins. Hemoglobin is a protein in red blood cells that carries oxygen. Many primates have hemoglobin that is almost identical.

Human Ancestors

Primates are divided into two major groups. The first group includes organisms such as lemurs and tarsiers. These animals have large eyes and are most active at night. The second group, the higher primates, includes monkeys, apes, and humans. About 6 million years ago the hominids, our earliest ancestors, branched off from the other higher primates. **Hominids** are humanlike primates that eat both meat and vegetables and walk upright on two feet. Hominids share some common characteristics with gorillas, orangutans, and chimpanzees. A larger brain size along with the characteristics mentioned above separated them from other great apes.

In 1924 Raymond Dart, a South African scientist, discovered an unusual fossil skull in a quarry in South Africa. The skull had a small brain cavity but humanlike jaw and teeth. Dart named his discovery *Australopithecus. Australopithecus,* one of the earliest hominid groups discovered, means "southern ape." In 1974, an almost complete skeleton of *Australopithecus* was discovered by an American scientist, Donald Johanson, and his colleagues. They named the fossil, estimated to be 2.9 to 3.4 million years old, Lucy. Lucy had a small brain but walked upright. Many scientists today think humans evolved in Africa from ancestors similar to Lucy.

Figure 6-16. The fossil remains of Lucy, a hominid, are estimated to be 2.9 to 3.4 million years old.



In Your JOURNAL

Using what you know of the characteristics of Neanderthal man, write an advertisement **in your Journal** for *The Neanderthal News* for a modern-day product that you think humans might have been able to use then.

About 40 years after the discovery of *Australopithecus,* a discovery was made in East Africa by Louis, Mary, and Richard Leakey. The Leakeys discovered a fossil more similar to present-day humans than *Australopithecus.* They named this hominid *Homo habilis,* the "handy man," because they found simple stone tools near him. Scientists estimate *Homo habilis* to be 1.5 to 2 million years old. Homo habilis is thought to be a direct ancestor of humans because it had a larger brain and was more similar in form to humans than *Australopithecus.*

Modern Humans

Our species is named ***Homo sapiens,*** meaning "wise human." The fossil record shows that the human species, a very recent arrival on Earth, evolved about 300 000 years ago. By about 125 000 years ago, two early groups of *Homo sapiens,* Neanderthal human and Cro-Magnon human, probably lived at the same time in parts of Africa and Europe.

Neanderthal humans had short, heavy bodies with thick massive bones, small chins, and heavy brow ridges. The Neanderthal humans lived in family groups in caves and hunted mammoths, deer, and other large animals with well-made stone tools. For reasons that are not clear, Neanderthal humans disappeared from the fossil record about 35 000 years ago.

Cro-Magnon fossils have been found in Europe, Asia, and Australia. These fossils are dated from 40 000 to about 10 000 years ago. Cro-Magnon humans are thought to

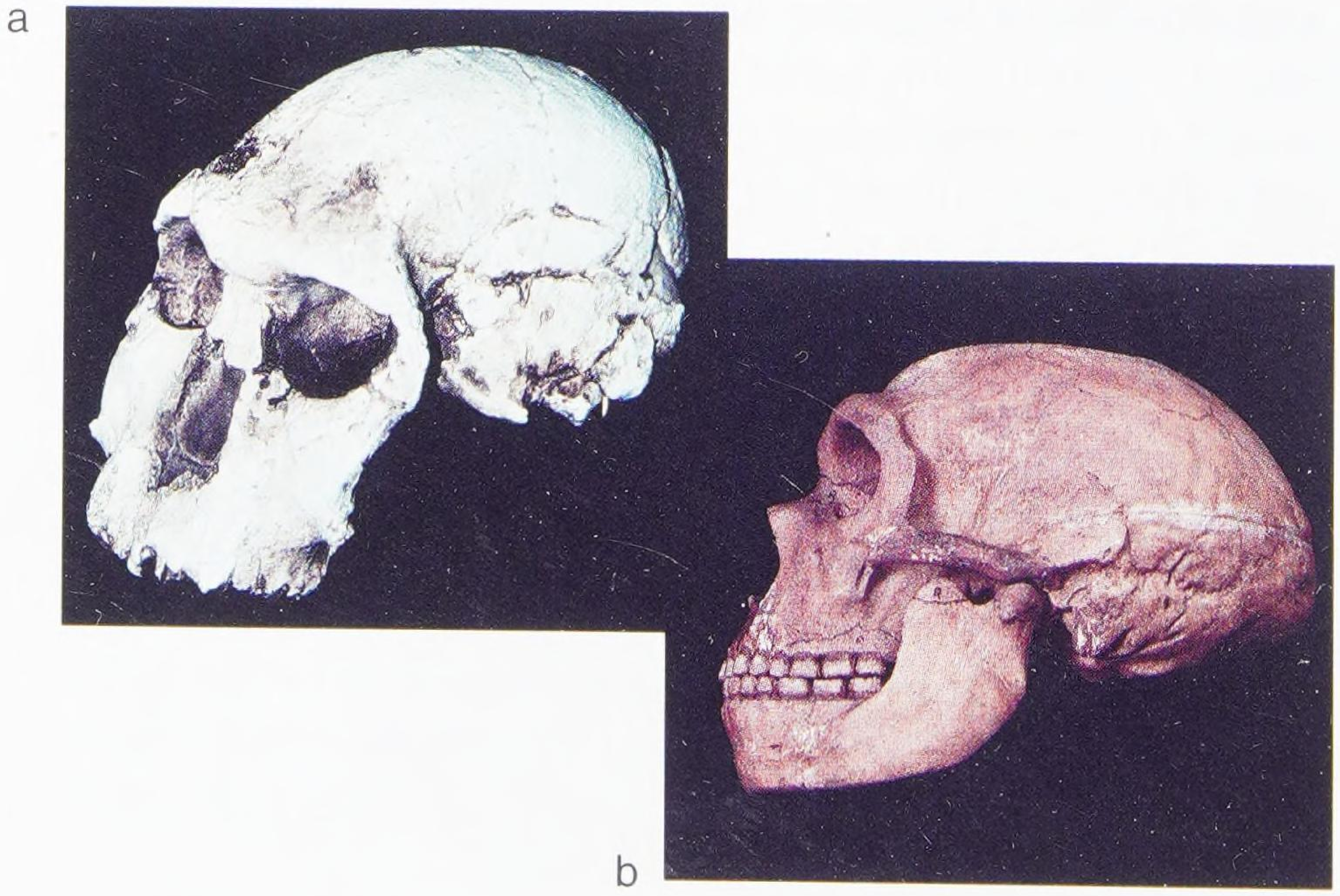


Figure 6-17. Fossil skulls of (a) *Homo habilis* and (b) Neanderthal are shown. Notice the larger brain area in the Neanderthal skull.

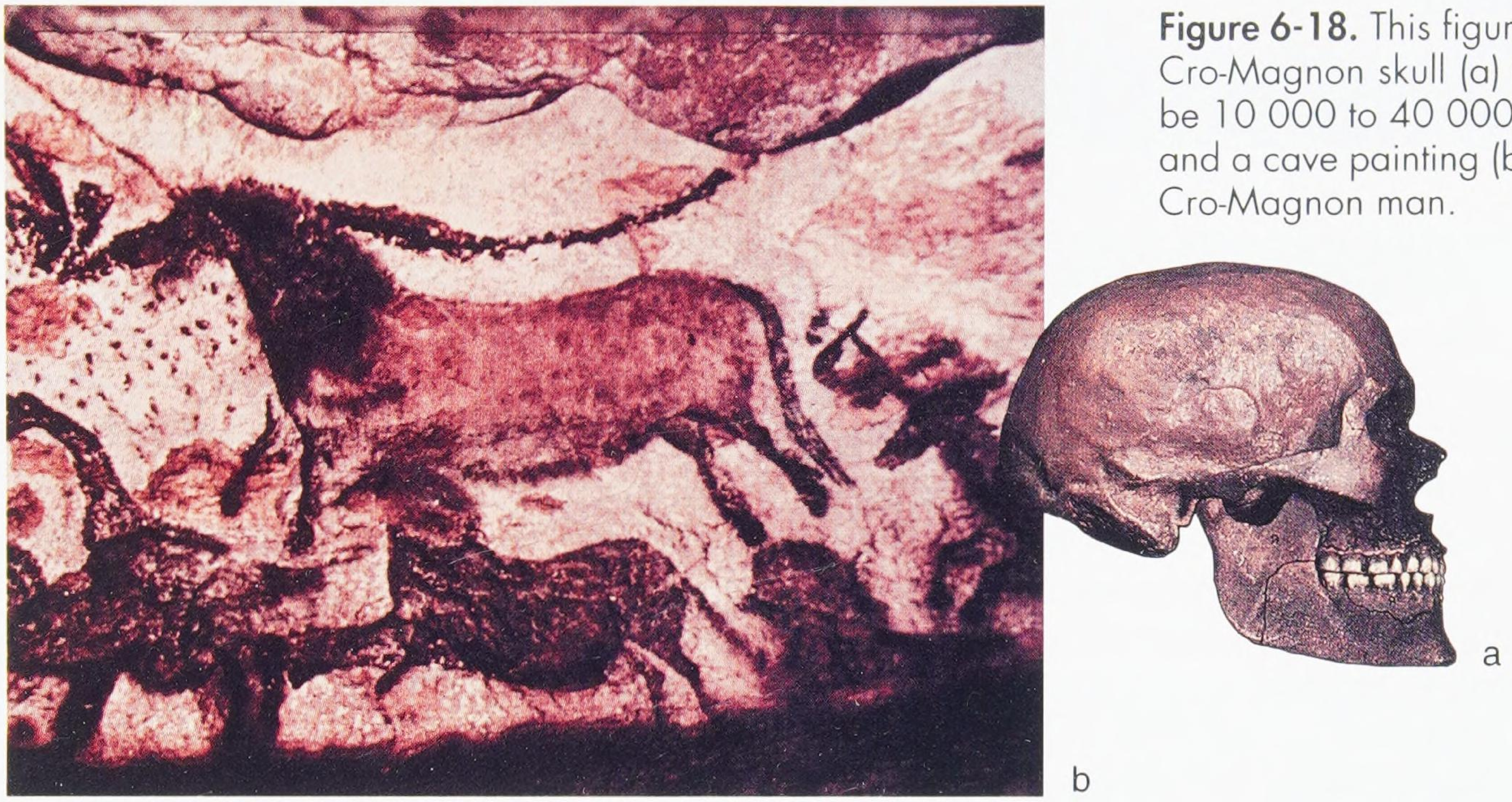


Figure 6-18. This figure shows a Cro-Magnon skull (a) thought to be 10 000 to 40 000 years old and a cave painting (b) done by Cro-Magnon man.

be the direct ancestors of modern humans. The oldest recorded art dates from the caves of France where Cro-Magnon humans first painted bison, horses, and spear-carrying people. Cro-Magnon humans lived in caves, made stone carvings, cared for their elderly, and buried their dead. Standing about 1.8 m tall, the physical appearance of Cro-Magnon people was almost identical to that of modern humans.

Connect to... Earth Science

Many fossils from hominids and early humans have been found in the African rift valley. This area of Africa is where two tectonic plates of Earth's crust are moving past one another. Why might you expect to find many fossils here?

SECTION REVIEW

1. Describe at least three kinds of evidence that suggests all primates shared a common ancestor.
2. What is the importance of *Australopithecus*?
3. Describe the differences between Neanderthal humans, Cro-Magnon humans, and modern humans.
4. **Apply:** How was an opposable thumb important in human evolution?
5. **Connect to Earth Science:** Propose a hypothesis about why teeth represent the most abundant available fossils of hominids.

Skill Builder

Concept Mapping

Using information is this section, make a concept map to show the sequence of human ancestors. Use the following terms: Neanderthal human, lemurs and tarsiers, *Homo habilis*, *Australopithecus*, modern *Homo sapiens*, Cro-Magnon human. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

DESIGNING AN EXPERIMENT

ACTIVITY 6-2

Recognizing Variations in a Population

Have you ever noticed that when you first see a group of plants or animals of a species that they all look alike? For instance, if you are walking in a field of sunflowers, the plants have basically the same appearance. But if you look closer, you notice that there are all kinds of variations. Some sunflower plants are slightly taller than others; some have leaves a little larger or a little greener than others growing close by. Variations must exist in a population for evolution to occur. In this exercise, you will be a scientist who makes a hypothesis about a trait found in a population of seeds. Then you will design and carry out an investigation to find out if seeds exhibit variations.

Getting Started

In preparation for designing your experiment, answer the following questions:

1. What is the question you will investigate?
2. How do seeds vary?

Safety Precautions

Don't eat seeds unless your teacher says that you may. Some kinds of seeds are poisonous.

Hypothesis

What is your **hypothesis?** What are your reasons for forming this hypothesis? Share this information with your group. Choose the best idea that can be tested in the classroom.

Brainstorm

In your group, make a list of possible ways to test your hypothesis.

Experimental Plan

- Design an investigation that will test only one variable. Make sure to collect data that can be represented as numbers.
- In a numbered list, similar to a recipe, make a set of directions that anyone can follow to do the experiment.
- Make a list of materials and the quantities you will need to do the experiment.

Answer the Following Questions

1. Do you need a control?
2. What will you measure?
3. How many seeds will you measure?
4. Develop a data table for collecting data and write in your data as you collect it.

Make sure your teacher has approved your experimental plan before you proceed further.

Data and Observations

Carry out your experiment, make your measurements, and complete your data table.

Data Analysis and Interpretation

1. What types of differences did you look for?
2. Was your **hypothesis** supported by your data? Explain.
3. What was the mean, median, and mode of your data?
4. The range of data is the difference between the smallest and the largest measurement in the investigation. What was your range of data? How does your range of data compare with other groups? Explain any similarities and differences.
5. Compare the mean, median, and mode of your data with results from other groups. Explain any similarities and differences.
6. Write a conclusion based on your data.

Going Further

Design another experiment that would reveal variations in another type of seed.

CHAPTER REVIEW

SUMMARY

6-1: Mechanisms of Evolution

1. Hereditary features of a species of organisms evolve or change over time.

2. Lamarck developed the theory of acquired characteristics to explain evolution. His theory implied that characteristics parents developed during their lives were passed on to their offspring. Charles Darwin developed the natural selection theory of evolution. According to this theory, organisms best adapted to their environments survive and reproduce.

3. Variations are differences in inherited traits among members of the same species. Variations can allow an organism to be better suited to its environment.

6-2: Evidence for Evolution

1. Fossils are remains of life from an earlier time. They give important evidence of evolution.

2. The age of a fossil can be found by using relative dating or radioactive dating. In relative dating, the age of a fossil is found by looking where it is in the rock layers. Radioactive dating determines the age of a fossil by comparing amounts of radioactive and stable substances in a fossil.

3. Evidence for evolution is obtained by comparing embryology, homologous structures, chemical similarities, and vestigial structures.

6-3: Science and Society: Plant and Animal Extinction

1. Extinction is the dying out of a species due to changes in the environment.

2. Endangered species can be saved from extinction by preserving their environments and by breeding them in captivity.

6-4: Human Evolution

1. Primates share several common characteristics including opposable thumbs, binocular vision, and flexible shoulders and rotating forearms.

2. The earliest known hominid is *Australopithecus*. Hominids are humanlike primates. The hominid *Homo habilis* is thought to be the direct ancestor of humans.

3. Modern humans, *Homo sapiens,* evolved 300 000 years ago. They most likely evolved from Cro-Magnon humans.

KEY SCIENCE WORDS

a. **embryology**
b. **endangered species**
c. **evolution**
d. **extinction**
e. **fossils**
f. **gradualism**
g. **hominids**
h. **homologous**
i. ***Homo sapiens***
j. **natural selection**
k. **population**
l. **primates**
m. **punctuated equilibrium**
n. **radioactive elements**
o. **relative dating**
p. **sedimentary rock**
q. **species**
r. **variation**
s. **vestigial structure**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. remains of once-living things
2. structure with no obvious use
3. similar organisms that successfully reproduce
4. body structures that are similar in origin
5. change in hereditary feature over time
6. a difference in an inherited trait
7. all the members of one species in an area
8. model of evolution showing slow change
9. the study of stages of an organism's early development
10. group containing monkeys, apes, and humans

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence or answers the questions.

1. _______ is the death of all members of a species.
   - **a.** Evolution
   - **b.** Extinction
   - **c.** Gradualism
   - **d.** Variation
2. The most accurate age of a fossil can be found using _______.
   - **a.** natural selection
   - **b.** radioactive elements
   - **c.** relative dating
   - **d.** camouflage
3. Homologous structures, vestigial structures, and fossils all provide evidence of _______.
   - **a.** extinction
   - **b.** species populations
   - **c.** food choice
   - **d.** evolution
4. A factor that controls natural selection is _______.
   - **a.** inheritance of acquired traits
   - **b.** unused traits become smaller
   - **c.** organisms produce more offspring than can survive
   - **d.** the size of an organism
5. A series of helpful variations in a species may eventually result in _______.
   - **a.** climate change
   - **b.** fossils
   - **c.** extinction
   - **d.** evolution into two species
6. Organisms adapted to their environment are _______.
   - **a.** extinct
   - **b.** not reproducing
   - **c.** surviving and reproducing
   - **d.** forming fossils
7. In order for evolution to occur, some change takes place in _______.
   - **a.** a single individual
   - **b.** an embryo
   - **c.** a population
   - **d.** the climate
8. Opposable thumbs and flexible shoulders are characteristics of _______.
   - **a.** all primates
   - **b.** hominids
   - **c.** humans only
   - **d.** monkeys and apes
9. The earliest paintings were done by _______.
   - **a.** *Australopithecus*
   - **b.** Cro-Magnon humans
   - **c.** *Homo sapiens*
   - **d.** Neanderthal humans

USING LAB SKILLS

10. Pretend that the pennies used in the Activity on page 143 each represent one milligram of radioactive material, and each time you shake the box represents one hundred thousand years. Make a line graph to show your results. Plot the mass on the x-axis and the time on the y-axis.
11. In the MINI-Lab on page 137, you made a model of an imprint fossil. Using clay, a stone, shell, or other small object of your choice, make a model of a cast fossil. How does a cast fossil differ from an imprint fossil?

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

12. Use Darwin's theory of natural selection to explain how the giraffe got its long neck.
13. Describe what causes variations and how the resulting adaptations help explain evolution.
14. What could happen if members of a population became completely separated from each other?

15. Compare gradualism and punctuated equilibrium.
16. Compare relative dating to radioactive dating of fossils. Which do you think is more accurate and why?

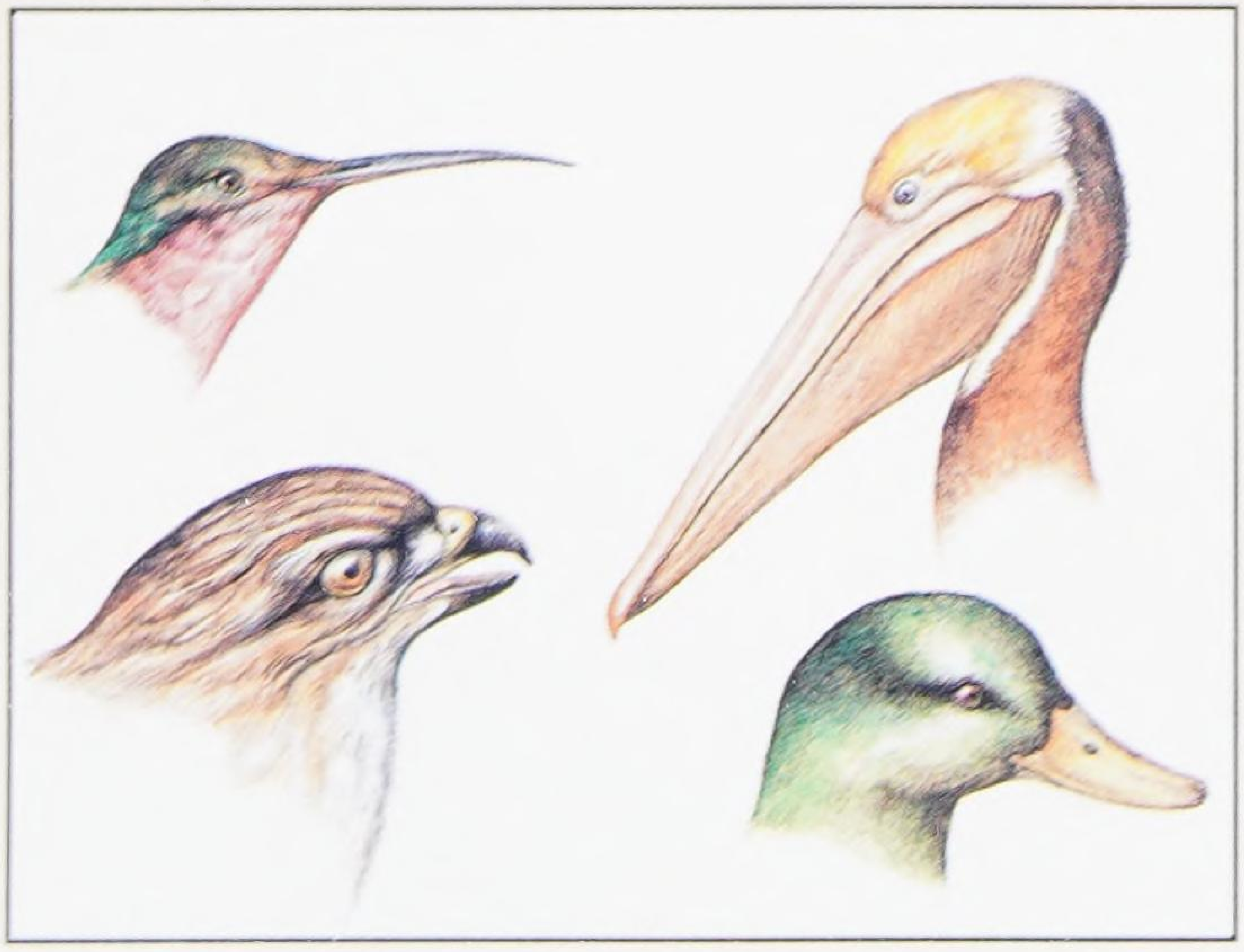
APPLY

17. Explain how Lamarck and Darwin would have explained a duck's webbed feet.
18. Using an example, explain how a new species of organism could evolve. (HINT: isolation, change in climate)
19. How is the coloration of chameleons an adaptation to their environment?
20. Describe the process a scientist would use to figure out the age of a fossil.
21. Explain how an organism could become extinct. Give an example.

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Observing and Inferring:** Observe the birds' beaks pictured below. Describe each. Infer the types of food each would eat and explain why.



2. **Hypothesizing:** Frog eggs are common in ponds in spring. Make a hypothesis as to why ponds are not overpopulated by frogs in the summer. Use the ideas of natural selection to help you.
3. **Comparing and Contrasting:** Compare and contrast Cro-Magnon humans and Neanderthal humans.
4. **Outlining:** Outline the events that led Charles Darwin to his theory of natural selection.
5. **Interpreting Data:** Interpret the following data. The chemicals present in certain bacteria were studied. Listed below are the chemicals found in each type. Each letter represents a different chemical. Use this information to determine which of the bacteria are closely related.

Chemicals Present	
Bacteria 1	A, G, T, C, L, E, S, H
Bacteria 2	A, G, T, C, L, D, H
Bacteria 3	A, G, T, C, L, D, P, U, S, R, I, V
Bacteria 4	A, G, T, C, L, D, H

PROJECTS

1. Make a collection of fossils found in your area. Identify where your fossils were found. If you live in a city, visit a museum of natural history and report on the fossil history of the land the city is built on.
2. Research the work of Alfred Wallace. On a world map, show the sites of his work and that of Darwin. Compare and contrast the areas in which they worked.

CHAPTER

7

Classification of Living Things

You might have visited a zoo and discovered creatures you didn't even know existed. How did you decide if an animal was a type of monkey or a type of bear? Or if it was a bird or an insect? Think about how you made these distinctions.

FIND OUT!

Do this simple activity to find out how you might determine relationships between organisms.

Observe the organisms on the opposite page. Notice that all of the organisms are insects, all have wings, and all of them can fly. Now look closely at each of the organisms. Group them based on specific traits that are shared. For example, organisms that have feathery antenna can be grouped together. You might also group the organisms based on color, size, shape, or any other traits you observe. You might find organisms that can't be grouped with the others. Now try to divide your groups into smaller, more specific groups. How many different groups did you make?

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 7-1 What Is Classification?
- Classifying
- Early History of Classification
- Scientific Naming

Section 7-2 Modern Classification
- Five-Kingdom System
- Prokaryotes and Eukaryotes
- Groups within Kingdoms

Section 7-3 Science and Society
The Rain Forest Crisis
- Undiscovered Treasures
- The Consequences

Section 7-4 Identifying Organisms
- Common Names and Scientific Names
- Making and Using Dichotomous Keys

Previewing Science Skills

- In the **Skill Builders,** you will observe and infer, make a concept map, and classify.
- In the **Activities,** you will classify and observe.
- In the **MINI-Labs,** you will classify, make models, and apply knowledge.

What's next?

Life scientists look at many physical traits to categorize living things. In this chapter, you will learn how and why scientists categorize living things. You will learn about the history of this process and scientists who have developed widely-used classification methods. Finally, you will learn about the five kingdoms of living things and the groups within the kingdoms.

7-1 What Is Classification?

New Science Words

classify
taxonomy
kingdom
binomial nomenclature
species
genus

Objectives

- Give examples that show the need for classification systems.
- Describe Aristotle's system of classification.
- Explain Linnaeus's system of classification.

Classifying

When you go into a grocery store do you usually go to one aisle to get milk, to another part of the store to get margarine, and to a third area to get yogurt? No, most grocery stores group similar items. The dairy products mentioned in the example above would be found together. When you place similar items together, you classify them. To **classify** means to group ideas, information, or objects based on similarities.

Classification is more a part of your life than you might think. Grocery stores, bookstores, and department stores group similar items together. In what other places is classification important?

MINI-Lab

How can leaves be classified?
Collect a variety of types of leaves. Place the leaves between sheets of newspaper and press in a heavy book. *Classify* the leaves based on similarities. Glue the leaves onto poster board in their groups. **In your Journal,** explain how you classified the leaves.

Early History of Classification

More than 2000 years ago Aristotle, a Greek philosopher, developed a system to group living things. The science of grouping and naming organisms is called **taxonomy** (tak SAHN uh mee). Aristotle began his system of taxonomy by dividing organisms into two large kingdoms, the plant and animal kingdoms. A **kingdom** is the largest of the taxonomic categories. Aristotle then divided the animal kingdom into smaller groups based on where animals live. Animals that live on land were in one group, animals that live in water were in another group,

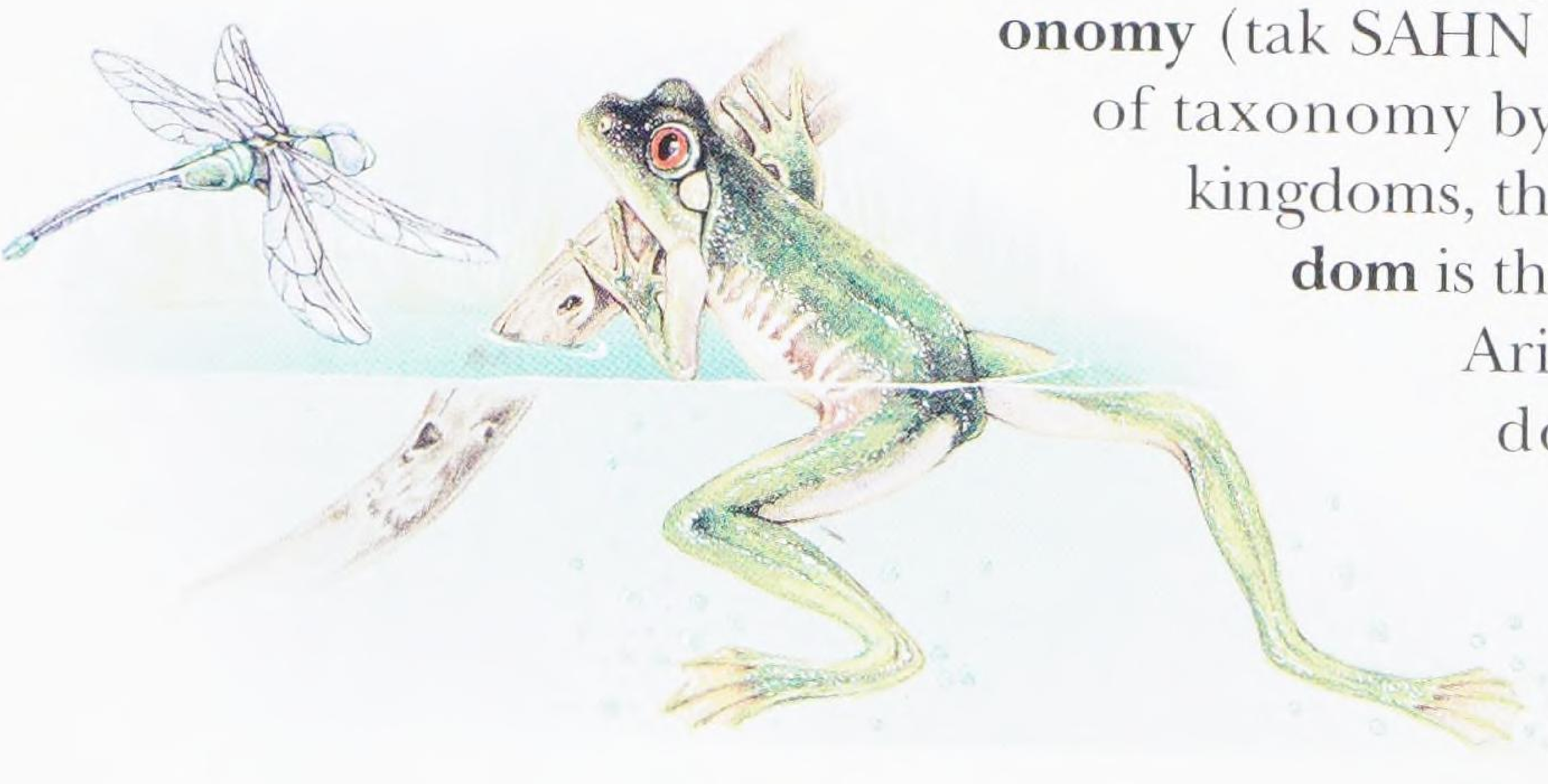


Figure 7-1. Why didn't frogs fit into Aristotle's system of classification?

and animals that fly through the air were in a third group. The plant kingdom was also divided into three groups based on size and structure.

Eventually scientists began to criticize Aristotle's system because it had too many exceptions. Animals were classified according to where they lived, but what about frogs? Frogs spend part of their lives in water and part on land. There was a problem with Aristotle's classification of plants also. Trees aren't all related just because they're trees. For example, an apple tree is more closely related to a rose bush than to a maple tree. A more logical classification system was needed.

Scientific Naming

Like Aristotle, Carolus Linnaeus (luh NAY us), a Swedish physician and naturalist, created a system to classify organisms based on similarities in body structures and systems, size, shape, color, and methods of obtaining food.

Linnaeus's system gives a two-word name to every organism. The two-word naming system is called **binomial nomenclature.** *Binomial* means "two names." The two-word species name is commonly called the organism's scientific name or Latin name. The first word of an organism's scientific name is the genus, and the second is the specific name. **Species** is the smallest, most specific classification category. A **genus** is the next largest category. It is a group of different species that are similar. Different species that belong to the same genus have common ancestors.

An example of a two-word, or species, name is *Felis catus.* This is a common house cat. Notice that the first word, the genus name, always begins with a capital letter. The second word, the specific name, begins with a lowercase letter. Both words in a scientific name are written in italic or underlined. Linnaeus chose the Latin language for his naming system because the meanings for Latin words are the same around the world and the language is unchanging. Another important result of Linnaeus's system is that no two organisms have the same scientific name. Because of Linnaeus's system and the use of Latin, scientists around the world recognize *Felis catus* as a house cat and not a Bengal tiger, *Felis tigris.*

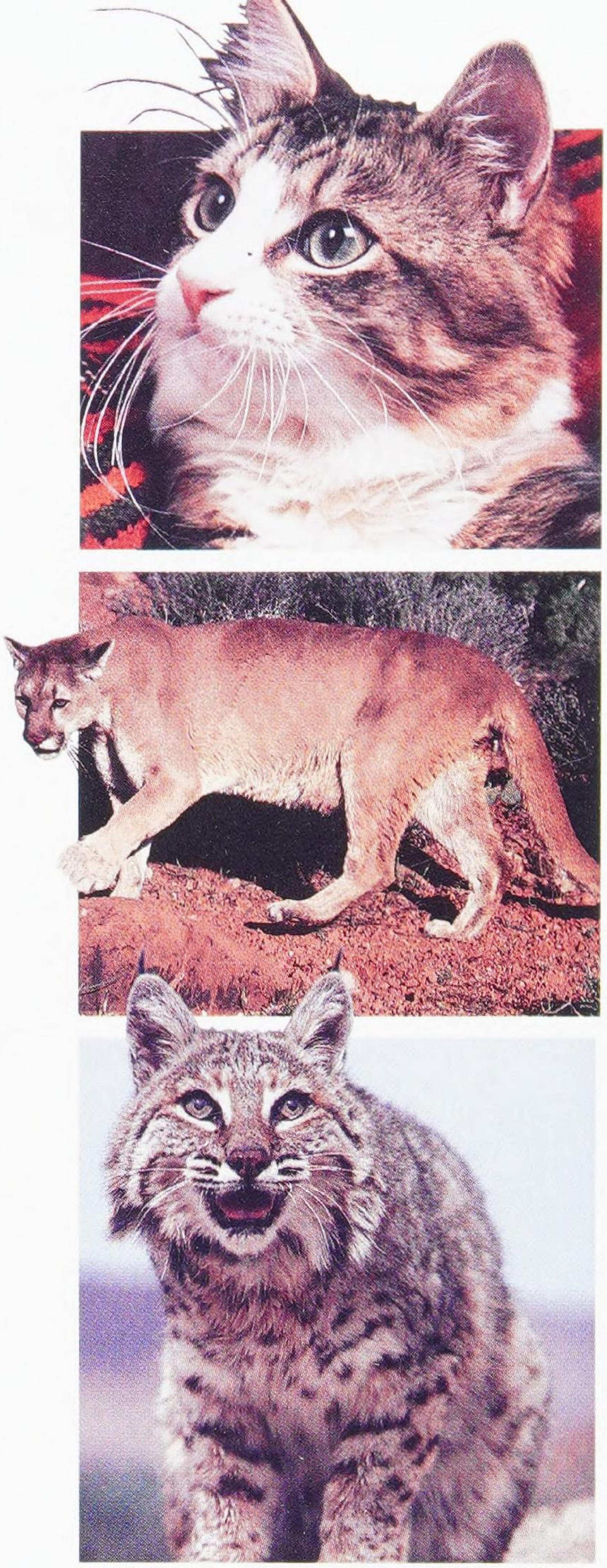


Figure 7-2. The top photo shows a housecat, *Felis catus.* Other members of the genus *Felis* are the cougar, *Felis concolor* (middle), and the bobcat, *Felis rufa* (bottom). Notice that there are three species, but that they all belong to the same genus.

PROBLEM SOLVING

Whose Shoe?

After the bell had rung, Mrs. Spencer announced, "Yesterday, we discussed how scientists classify organisms. Today, I want you to report to your learning groups and develop a classification system for the shoes of the members of your group."

Dani's group divided the shoes into two kingdoms, one with shoelaces and one without. Then, the group divided the laces group into white and nonwhite shoes. Because Dani's white shoes had rubber soles and Mike's had leather soles, the type of sole was the characteristic the groups chose to subdivide the white shoe group. The group then divided the nonwhite shoes group into brown for Colleen's shoe and black for Albert's shoe.

The kingdom without laces was easy to divide. Maria's shoe was a penny loafer, and Lauren's shoe was a white sandal.

Whose shoe is a white shoe with laces and a leather sole?

Think Critically: Diagram the classification system developed by Dani's group.

SECTION REVIEW

1. What is the purpose of classification?
2. Compare and contrast Aristotle's and Linnaeus's classification systems.
3. **Apply:** List two examples of things that are classified based on their similarities.
4. **Connect to Physics:** Matter is classified into three states. What are these states?

Skill Builder

Observing and Inferring

What could you infer about the following species of oaks: *Quercus alba, Quercus rubra, Quercus suber, Quercus macrocaroa*. If you need help, refer to Observing and Inferring in the **Skill Handbook** on page 682.

ACTIVITY 7-1

Classifying Seeds

Problem: *In what ways can seeds be classified?*

Materials

- packet of 10 different seeds
- hand lens
- metric ruler
- 2 sheets of paper

Procedure

1. Empty the packet of seeds on a sheet of paper. *Observe* each seed carefully.
2. Divide the 10 seeds into two groups, I and II. The seeds in each group must have at least one thing in common. For example, you could classify round seeds in Group I and seeds that are not round in Group II.
3. Record the characteristic that Group I seeds have in common in a chart like the one shown. Record the characteristics that Group II seeds have in common.
4. Now, divide the Group I seeds into two groups. Again, the seeds in a group must have something in common. Record in the chart the characteristics that the seeds in each group have in common.
5. Divide the seeds into two groups again. Record the characteristic that the seeds in each group have in common.
6. Repeat Step 5 two more times.
7. Repeat Step 4 through 6 with Group II.
8. Give the seed packet and chart to another person. Ask that person to *identify* each seed using your classification system.

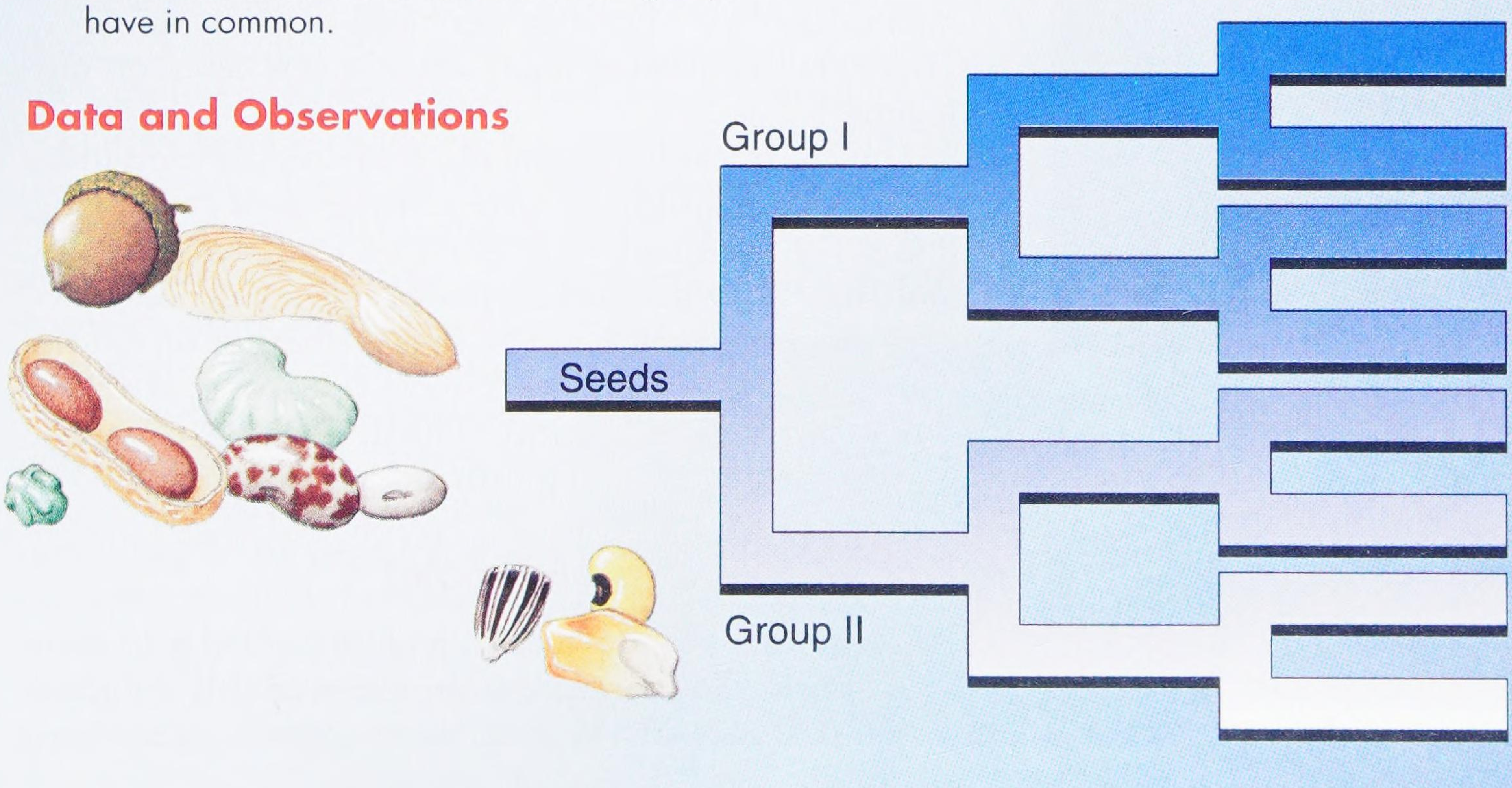
Analyze

1. What characteristic did you use to separate the seeds into the first two groups?
2. In what ways can groups of different types of seeds be classified?

Conclude and Apply

3. How is *classifying* helpful?
4. Why is it an advantage to scientists to use standardized classification systems? What observations did you make that support your answer?

Data and Observations



7-2 Modern Classification

New Science Words

phylogeny
phylum
division
classes
orders
families

Objectives

- Name the five kingdoms of living things.
- Identify characteristics and members of each kingdom.
- List the groups within each kingdom.

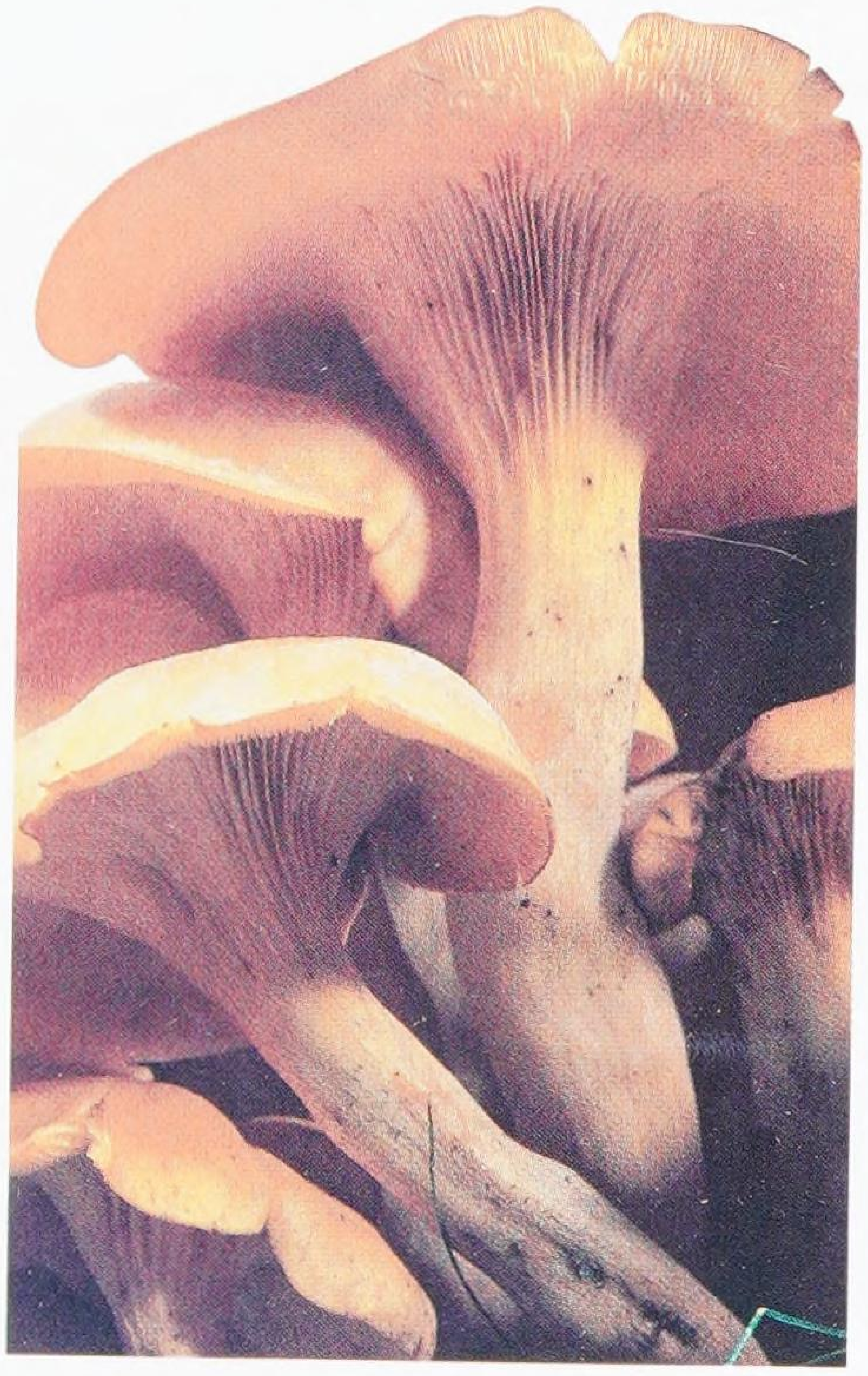


Figure 7-3. These colorful mushrooms are members of Kingdom Fungi.

Five-Kingdom System

How does the classification system used today by scientists differ from those of the past? Aristotle and Linnaeus developed their systems of classification using only characteristics of organisms that were easily observed. Besides easy to see characteristics, scientists today look at other types of traits to classify organisms. They look at the chemical makeup of the organism and its ancestors. Scientists find relationships among organisms by looking at similarities in genes and body structures. They also study fossils and the embryo of an organism as it develops. By studying all these things, scientists can determine an organism's phylogeny. The **phylogeny** of an organism is its evolutionary history. Phylogeny tells scientists who the ancestors of an organism were and helps in classify it. Today classification of many organisms is based on phylogeny.

The classification system most commonly used today separates organisms into five major groups called kingdoms. The five kingdoms are Animal, Plant, Fungi, Protist, and Monera. Organisms are placed into a kingdom based on four characteristics. The first is whether or not the cells of the organism have a nucleus. Second, are there one or many cells present? Third, does the organism make its own food? And fourth, does the organism move?

Prokaryotes and Eukaryotes

Kingdom Monera is made up of one-celled organisms that are simple structures. Members of this kingdom include bacteria such as streptococcus, which causes strep

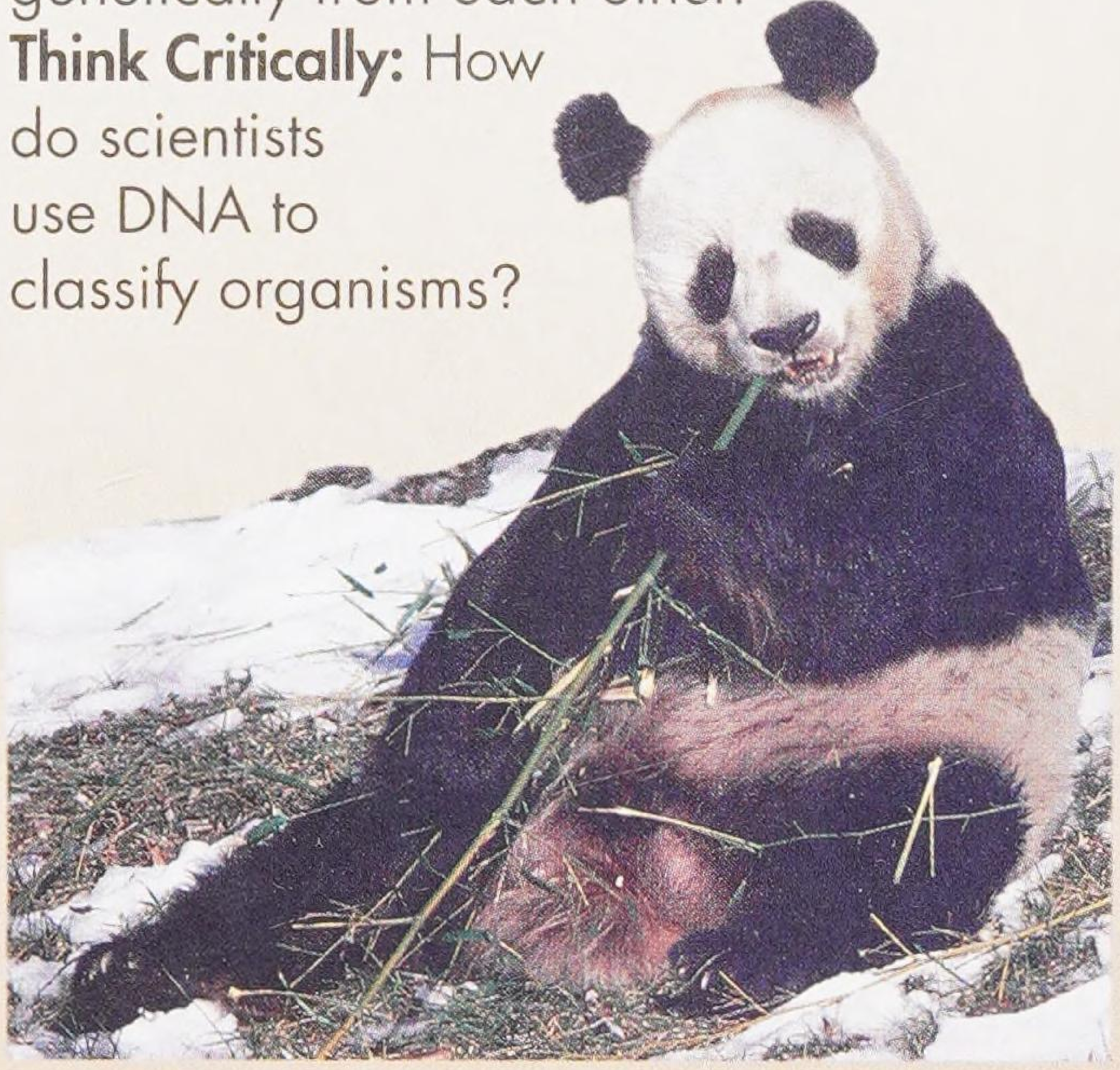
TECHNOLOGY

Beyond Appearances

Besides looking at an animal's physical traits, scientists now check out an animal's DNA to classify it. The more similar the DNA between two animals is, the more closely they are related. By using DNA information, scientists can tell which similar animals are actually separate species. They can also study how geographic separation and other factors affect populations. The information scientists gather helps zoos and wildlife programs conserve many species of animals.

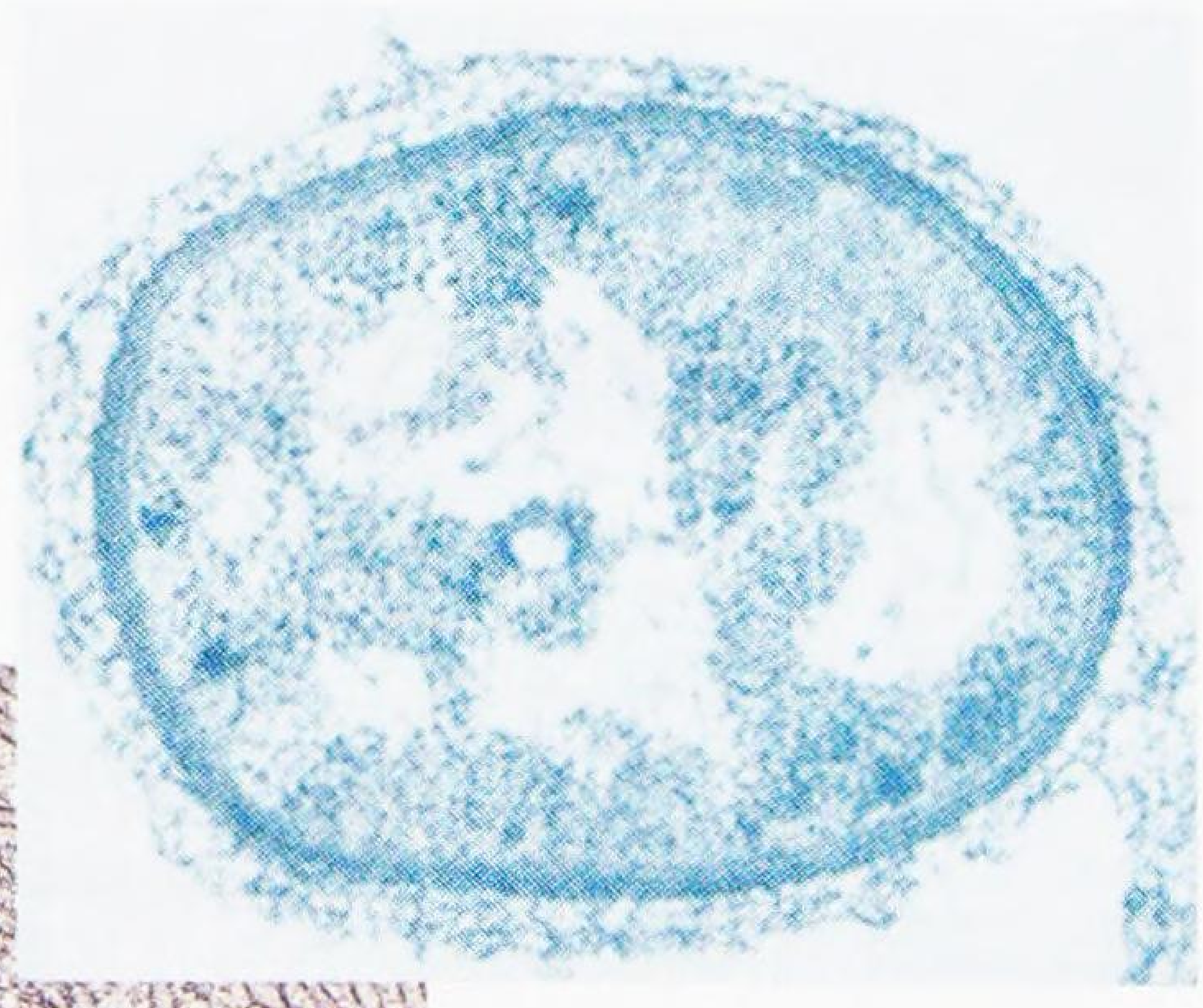
Genetic studies are already changing the way some organisms are classified. By studying DNA, scientists have found that pandas really are bears, and not relatives of the raccoon as they once thought. The "Asiatic" lions in U.S. zoos are not truly from Asia. They have African genes as well. White rhinos in North and South Africa are genetically the same in spite of being separated by 2000 miles. Some gray foxes living on islands off California's coast vary genetically from each other.

Think Critically: How do scientists use DNA to classify organisms?



throat, and cyanobacteria, a one-celled plantlike organism found in lakes and ponds. Unlike members of the other kingdoms, monerans don't have an organized nucleus surrounded by a membrane. They are also missing cell organelles. Because monerans don't have an organized nucleus or organelles they are called prokaryotes. *Prokaryote* means "before nucleus." All organisms other than bacteria and cyanobacteria are eukaryotes. Eukaryotes are organisms with a nucleus and organelles surrounded by membranes. *Eukaryote* means "true nucleus." Figure 7-4 shows the differences between prokaryotes and eukaryotes. Table 7-1 on page 162 gives examples and basic information about each of the five kingdoms. You will learn more about each kingdom in coming chapters.

Figure 7-4. A prokaryotic cell (a) has no nucleus. A nucleus is seen in the eukaryotic cell (b).



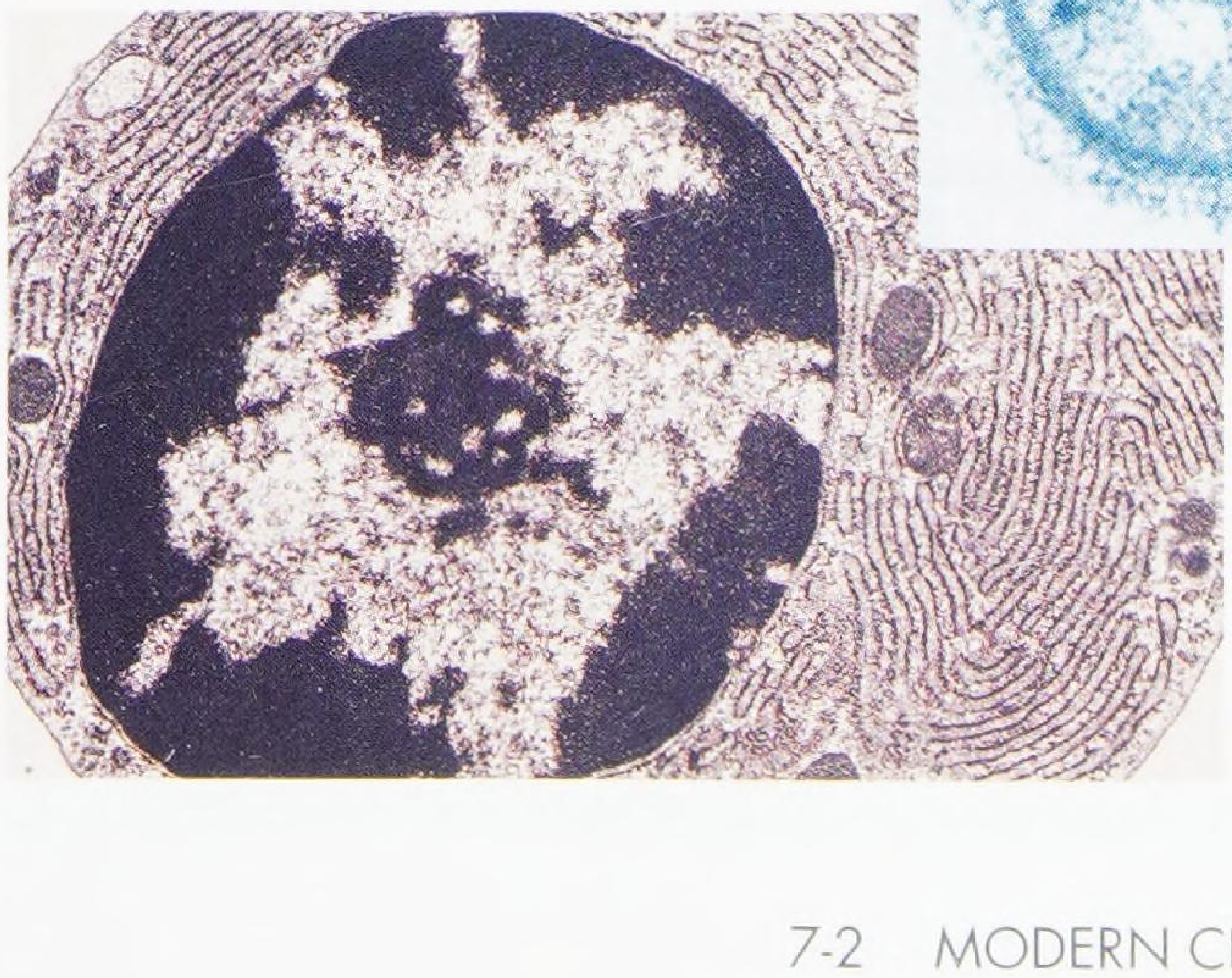
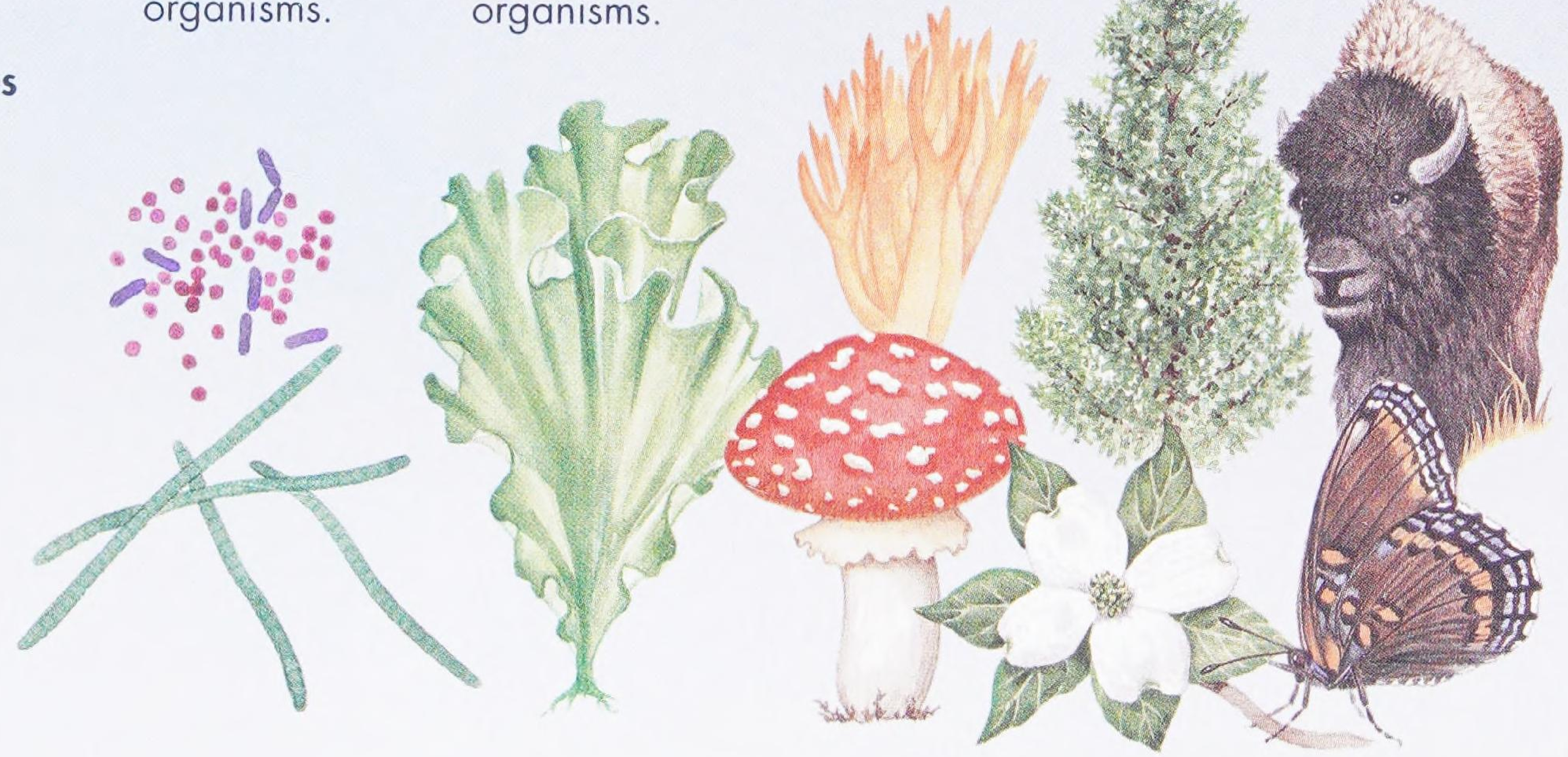


Table 7-1

LIFE'S FIVE KINGDOMS

	Monera	**Protist**	**Fungi**	**Plant**	**Animal**
Type of cells	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
One-celled or Many-celled	One-celled	One- and many-celled	One- and many-celled	Many-celled	Many-celled
Movement	Some move	Some move	Don't move	Don't move	Move
Nutrition	Some members make their own food, others obtain it from other organisms.	Some members make their own food, others obtain it from other organisms.	All members obtain food from other organisms.	Members make their own food.	Members eat plants or other animals.
Examples					

Connect to... Earth Science

Rocks are grouped into three main categories: igneous, sedimentary, and metamorphic. Find out the characteristics of igneous and metamorphic rocks.

Groups within Kingdoms

Imagine you received some money for your birthday. You decided to spend the money on the new tape you've been wanting, so you go to a music store at the mall. Now what do you do? Will you look through all the tapes in the store until you find the one you're looking for? You don't have to because the tapes are separated into categories of similar types of music such as rock, soul, classical, country, and jazz. Within each category, the tapes are divided by artists, and then into specific titles by the artist. Because of this classification system, you can easily find the tape you want.

Scientists classify organisms into groups in just the same way. Organisms are placed into kingdoms. Each kingdom is separated into six groups, each smaller than the one before it. The largest group within a kingdom is a **phylum.** In the plant and fungi kingdoms, the word **division** is used in place of phylum. Each phylum or division is separated into **classes.** Classes are separated into **orders,** and orders are separated into **families.** A genus is a group within a family. A genus can have one or more species.

Scientists go through this series of categories to name a specific organism the same way you went through a series of categories to find your tape. To understand how an organism is classified, look at the classification of the Arctic wolf in Figure 7-5. Each grouping shows organisms that have more in common. Each grouping also contains fewer organisms. When you reach species, a specific organism has been named, the Arctic wolf.

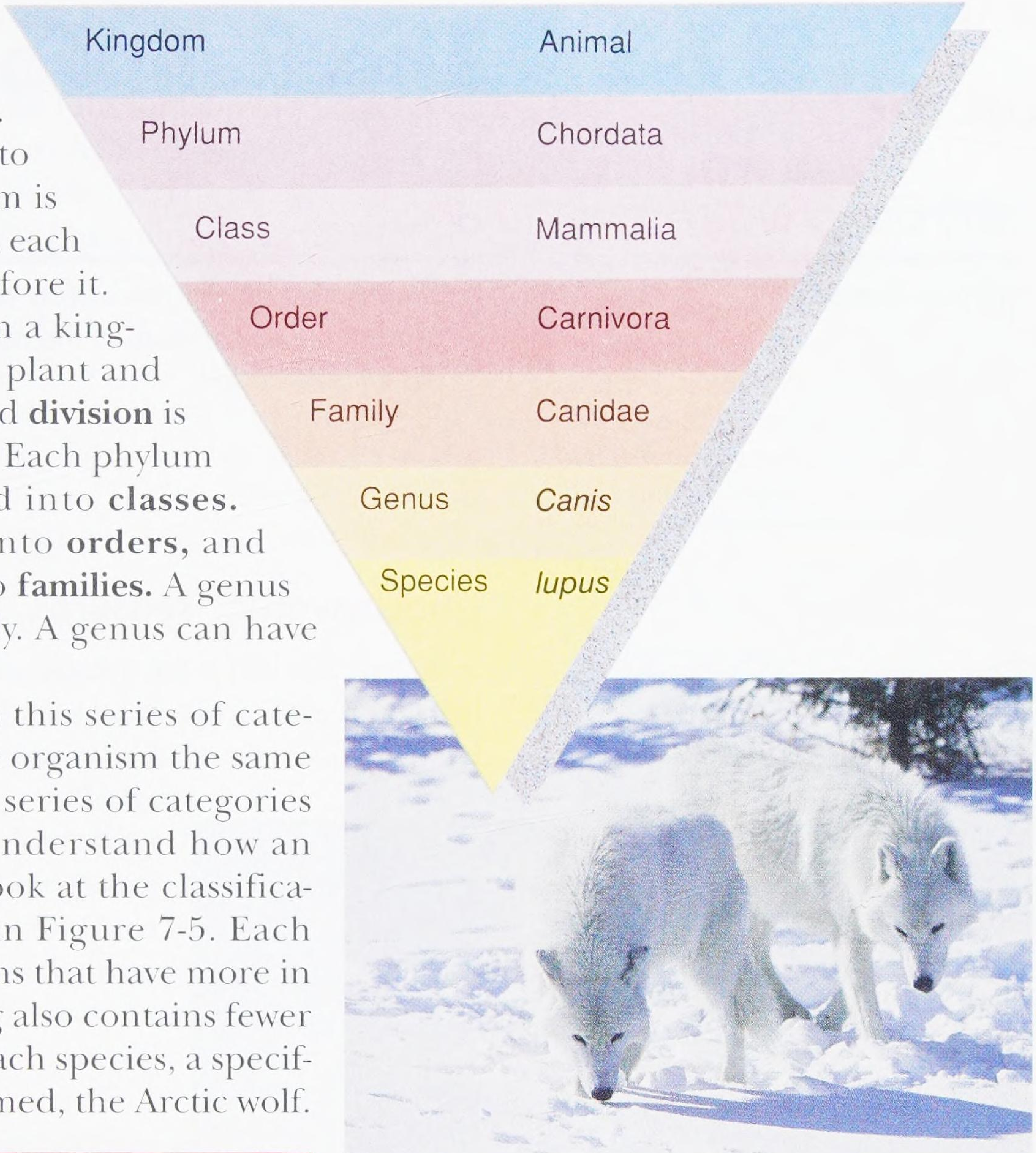


Figure 7-5. The classification of the Arctic wolf shows its genus to be *Canis* and species to be *Canis lupus*.

SECTION REVIEW

1. Name and describe each kingdom. Identify a member of each.
2. Why are there smaller groups within each kingdom?
3. **Apply:** What kingdom does a single-celled, eukaryotic organism that makes its own food belong in?
4. **Connect to Chemistry:** Elements are classified into families in the periodic table. How many element families are there?

Concept Mapping

Skill Builder

Use the following terms to make a network tree concept map. Provide your own linking words. *Cells, cell organelles, eukaryote, prokaryote, plants, animals, cyanobacteria, bacteria, no cell organelles, no nucleus, fungi, protists, organized nucleus.* If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

SCIENCE & SOCIETY

7-3 The Rain Forest Crisis

New Science Words

species diversity

Objectives

- Identify two dangerous effects of tropical deforestation.
- Explain the importance of the rain forest to us and to the people who live there.

Undiscovered Treasures

There are still a few places on Earth that have escaped human technology. Places such as dense, humid jungles hold thousands of undiscovered and unnamed species of plants and animals. The tropical rain forests of South America are just those places. Life there has gone on undisturbed for thousands of years, but this may all soon come to an end. There is a crisis occurring at this very moment.

There is no time to waste. Every minute, more than 50 more acres of rain forest are cleared for farming, or cut for timber. Many organizations are hard at work to explore these mysterious rain forests and help stop deforestation, the destruction of forests. Each year, hundreds of field biologists hunt through the dense tropical forests to unlock their mysteries. They want to learn as much as possible about the plants and animals that live there before these organisms become extinct. Scientists think that only about 15 percent of all the species of plants and animals there have been identified. The rest may never be discovered. This great variety of plants and animals, or **species diversity,** in the rain forests of the world is being destroyed by humans at a rapid rate. In the next 30 years we may lose one-fourth of all the species alive today.

Figure 7-6. Many species of animals and plants will be lost if deforestation continues.

The Consequences

Will the destruction of the rain forest really affect you? Is the effort to save the forest really necessary? Scientists think so. Along with saving species of animals, saving the trees and plants is also very important. Our atmosphere is very dependent on them to remove carbon dioxide and produce oxygen. The air that we breath in the United States will be affected by the loss of tropical forests. The damaged atmosphere may cause changes in weather patterns and dangerous storms. The climate of areas of the United States could also change. The northeastern region could have the tropical climate of Florida. And the southeast may become a desert.

Wild animals and plants aren't the only ones dependent on the rain forest lands for survival. The native people depend on farming these areas for survival. Remember how the pioneers settled America? They were starving to death and many died before they cleared thousands of acres and mastered farming. The people of many tropical areas are in the same situation. They are dependent on farming or logging for their income and survival. Farming is very destructive to rain forests because they have poor soils. An area can be farmed for only a few years before it is no longer fit to raise crops. A new piece of forest must then be cleared to be used for farming. Every few years the people must cut a new area of forest to grow crops to survive.

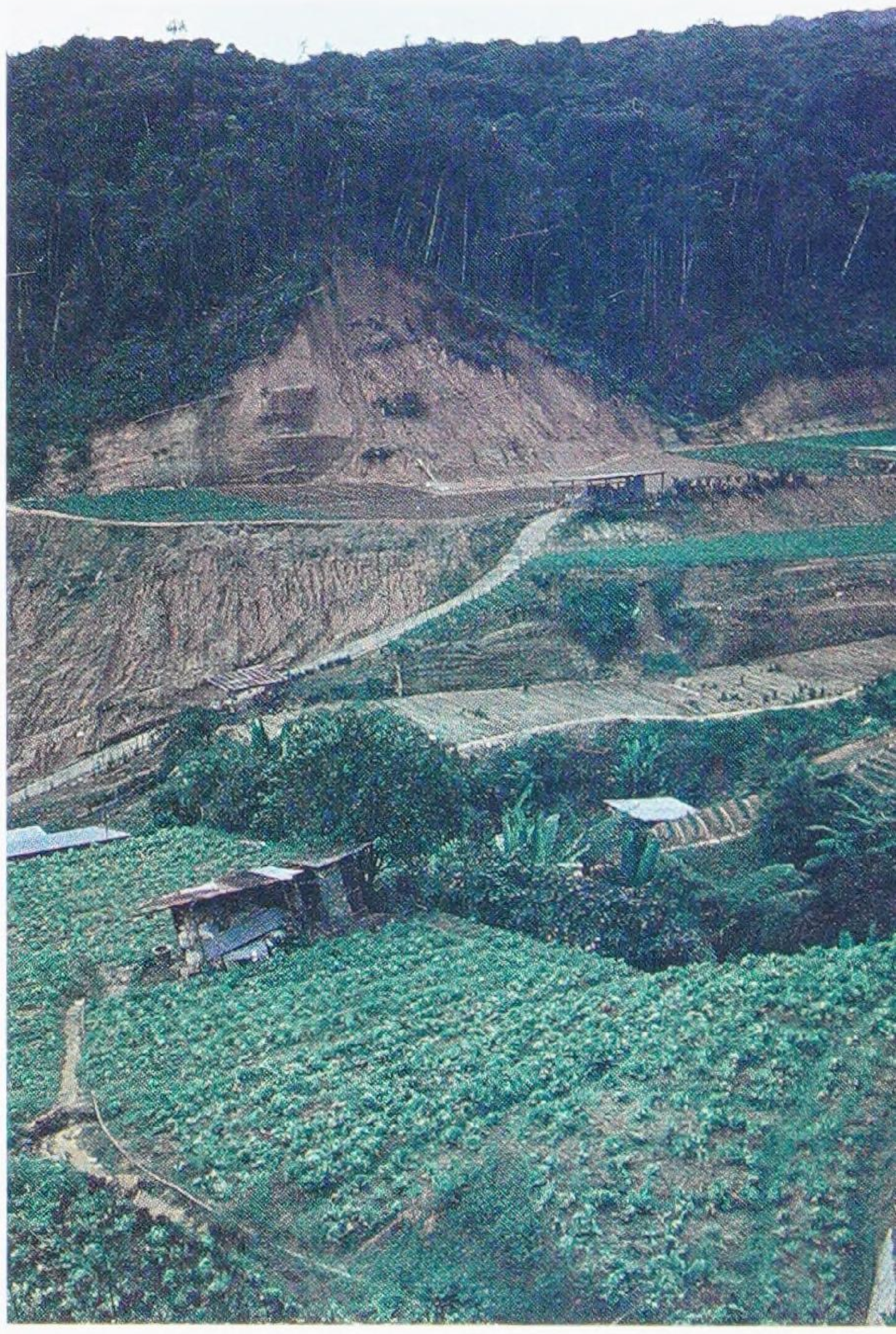
SECTION REVIEW

1. Why is tropical deforestation a concern to people in North America?
2. How are the native people dependent on rain forest lands?
3. **Connect to Earth Science:** Look at a world map and find out in what latitudes tropical rainforests are found.

In Your JOURNAL

Choose one of the rain forest plants, animals, or products listed here to research: toucans, squirrel monkeys, mahogany, kapok, curare, sloths, and bromeliads. Make a drawing of your choice **in your Journal**, and describe its location and its importance.

Figure 7-7. Rain forests are cleared for farming.



You Decide!

SCIENCE & SOCIETY

Much of the research on the tropical rain forests is being conducted by scientists from countries outside the rain forest, such as the United States. Is it right for the United States to purchase and preserve land that other people depend upon for survival? Should another society walk into their homeland and demand that the rain forest destruction stop?

7-4 Identifying Organisms

New Science Words

dichotomous keys

Objectives

- List reasons scientific names are more useful to scientists than common names.
- Identify the function of a dichotomous key.
- Demonstrate how to use a dichotomous key.

Common Names and Scientific Names

Have you ever seen a bird like the one in Figure 7-8a? What do you call it? Have you heard anyone call this bird a *Turdus migratorius*? In much of the United States this bird is commonly called a robin, or a robin redbreast. However, people who live in England call the bird in Figure 7-8b a robin. In much of Europe the same bird is called a redbreast. If you lived in Australia, you'd call the bird in Figure 7-8c a robin, or yellow robin. Are these the same species of bird? No, these birds are obviously very different from one another. Yet they all have the same or a similar common name. If you were talking informally to someone in your area who knew the same birds you did, you could use common names. But the common names for the different birds could be confusing if you were in another country or in another area of the same country.

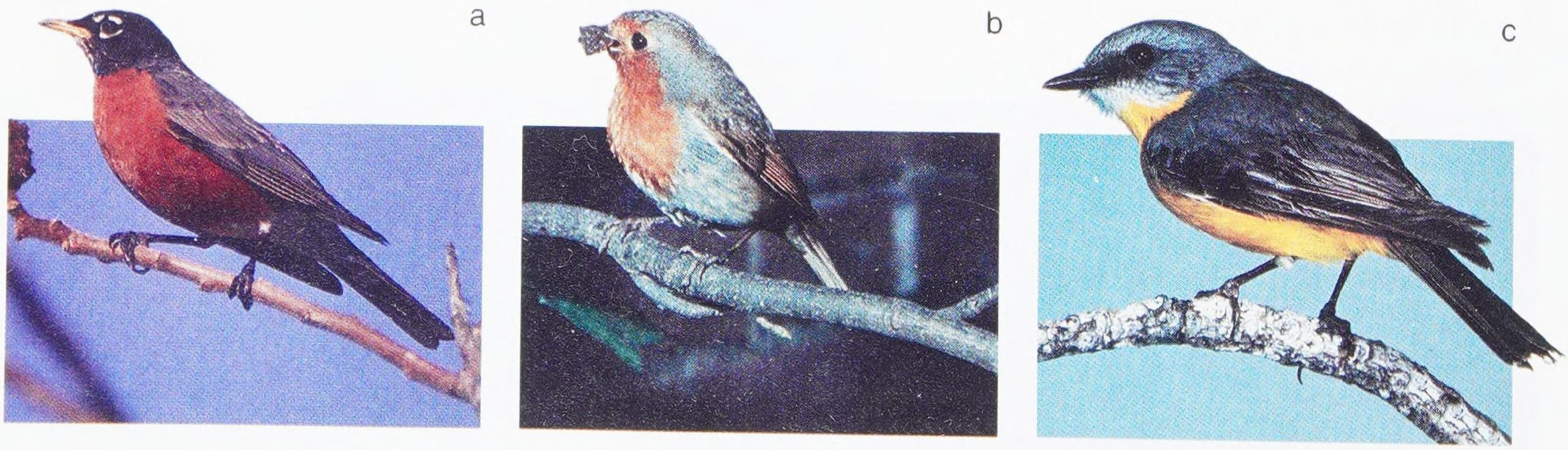
What would happen if life scientists used only common names when they tried to share information about the organisms they study? Many errors in understanding would probably result from the confusion. The system of binomial nomenclature developed by Linnaeus gives

MINI-Lab

How are organisms named?

Make a fictitious organism out of clay. Give your organism a scientific name. Be sure the name is Latinized and *infers* information about its species. Present your organism and its name to the class.

Figure 7-8. These three robins have the same common name, yet they are three different species.



each of these birds a unique scientific name. The scientific name for the bird in 7-8a is *Turdus migratorius.* The name for the bird in 7-8b is *Erithacus rubecula.* The name for the bird in 7-8c is *Eopsaltria australis.*

Scientific names serve four basic functions. First, scientific names help life scientists avoid errors in communication. A life scientist who studied yellow robins, *Eopsaltria australis,* would not be confused by information he or she read about *Turdus migratorius,* the American robin. Second, organisms with similar evolutionary histories are classified together. Because of this you know that organisms that share the same genus name are more related than those that don't. Third, the scientific name gives descriptive information about the species. What can you tell from the species name *Turdus migratorius*? It tells you that this bird must migrate from place to place. Fourth, the scientific names allow information about organisms to be organized and found easily and efficiently. Scientific names are used in guides to organisms called dichotomous (DI kaht uh mus) keys.

In Your JOURNAL

Select a field guide for flowers, trees, butterflies, birds, or mammals. **In your Journal**, write a book report describing the parts of the field guide. Select two organisms in the field guide that closely resemble each other. *Compare* them and explain how they differ, using labeled diagrams.

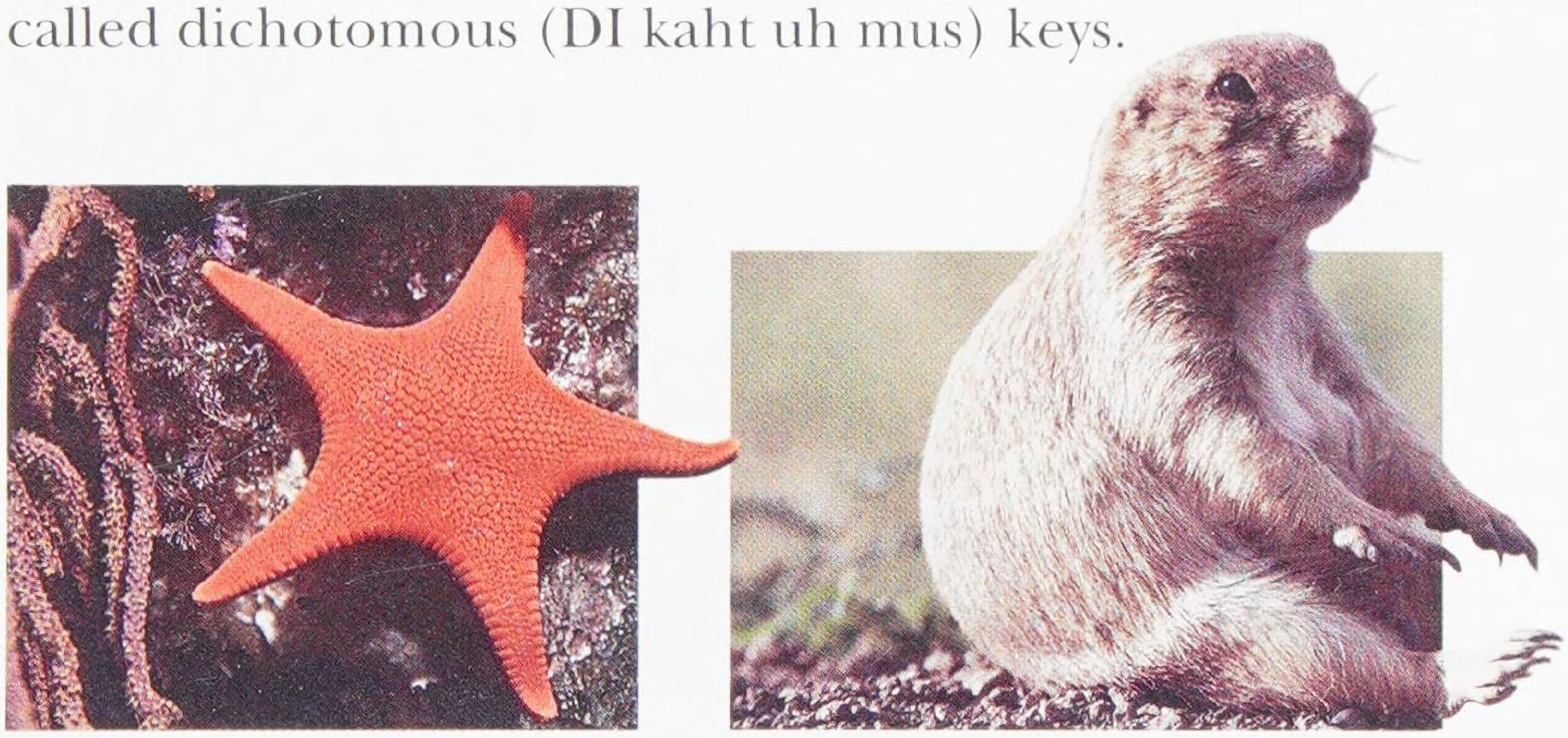


Figure 7-9. Common names can be misleading. Starfish are not fish and prairie dogs are more closely related to squirrels than to dogs.

Making and Using Dichotomous Keys

How would you go about finding out the name of an insect like the one pictured on page 168 in Table 7-2? The easiest way would be to ask an expert on insects, an entomologist at a college in your area. However, no one knows, or is even expected to know, all of the insects or any other major taxonomic group. The first thing the expert might tell you is that the insect is some kind of stag beetle. But, if you don't live near a college or natural history museum, what can you do? Should you give up? No, your next step should be to consult a field guide that contains descriptive guides as an aid to identification. Field guides can be found in a library.

Connect to... Earth Science

Keys can also be used to identify minerals. These keys are based on characteristics such as hardness, luster, color, streak, and cleavage. **Hypothesize** why you might need to know several characteristics to identify a mineral.

The keys found in most field guides are arranged in steps with two descriptive statements at each step. These keys are called **dichotomous keys.** Look at the dichotomous key for beetles in Table 7-2. Notice that the descriptions are labeled 1a and 1b, 2a and 2b, and so on. To use the key, you must always begin with a choice from the first pair of descriptions. Notice that the end of each description is either the name of a species or directions to go on to another step. If you use the dichotomous key properly, you will eventually wind up with the correct name for your species.

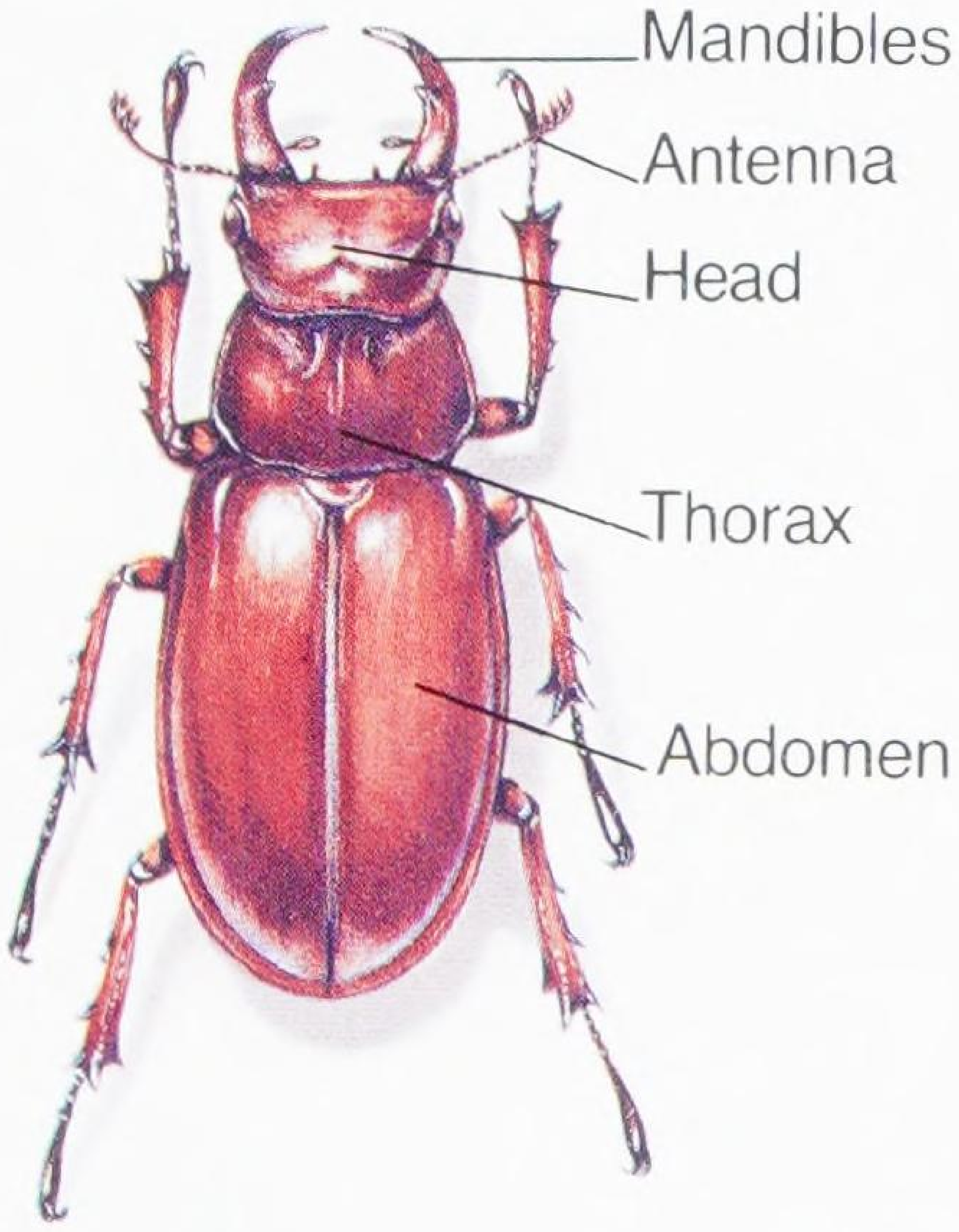
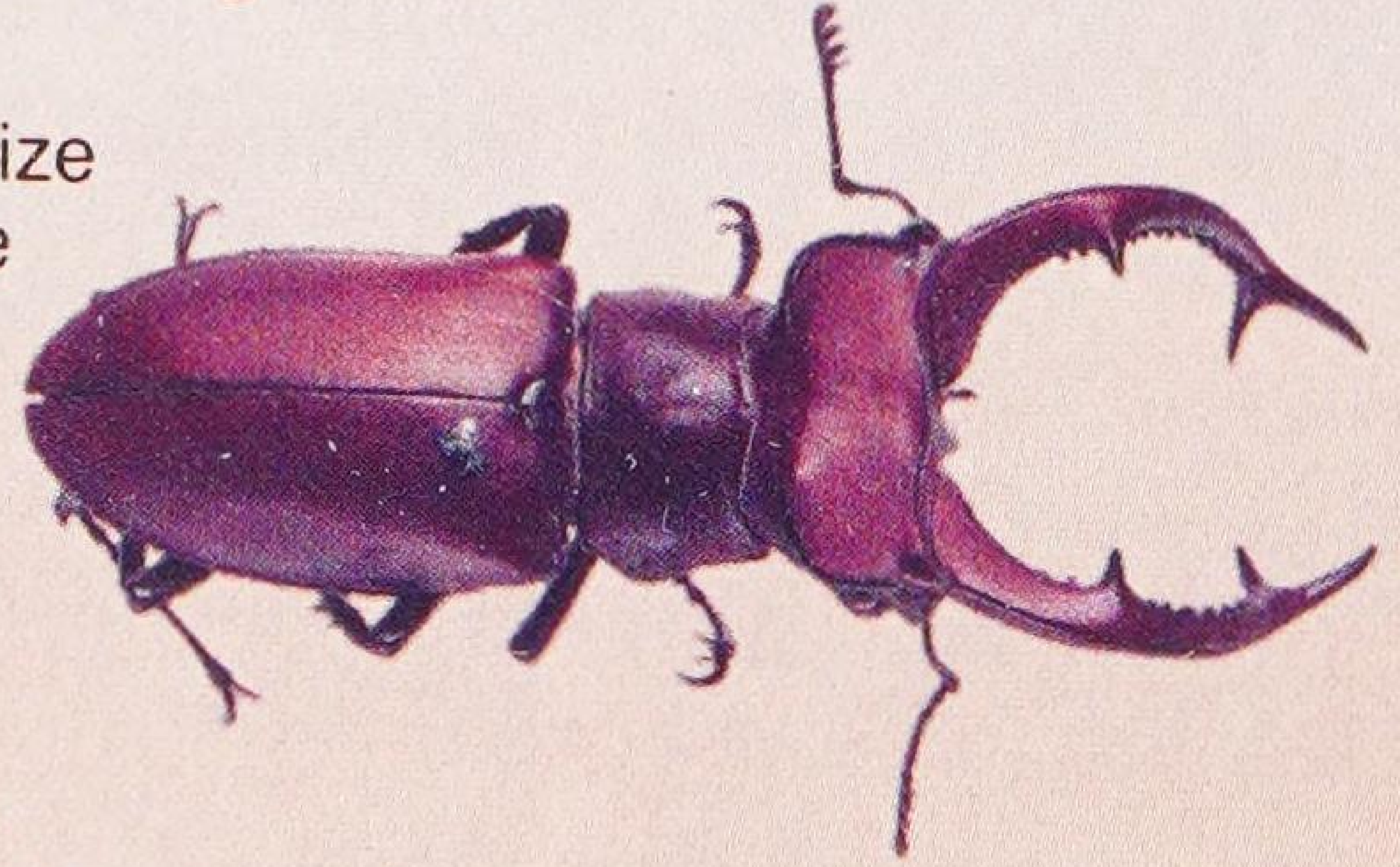


Figure 7-10. The external structures of a stag beetle

Table 7-2

SOME COMMON BEETLES OF NORTH AMERICA	
1a	If the beetle is longer than 20 mm, go to Step 2.
1b	If the beetle is less than 20 mm long, go to Step 5.
2a	If it is reddish brown, go to Step 3.
2b	If it is dark brown or black, go to Step 4.
3a	If the beetle has an oval patch of golden hairs on the front legs, it is commonly called a pinching bug, *Pseudolucanus capreolus.*
3b	If the beetle has no golden hairs on the front legs it is also called a pinching bug, *Pseudolucanus placidus.*
4a	If it is less than 30 mm long and the mandibles do not overlap, it is commonly called an antelope beetle, *Dorcus parallelus.*
4b	If it is more than 30 mm long with large overlapping mandibles, it is commonly called the elephant stag beetle or giant stag beetle, *Lucanus elaphus.*
5a	If the head is as wide as the thorax and it is reddish black, it is an oak stag beetle, *Platycerus agassizi.*
5b	If the head is much narrower than the thorax with a backward-directed horn, it is a rugose stag beetle, *Sinodendron rugosum.*



The actual size of this beetle is 50 mm.

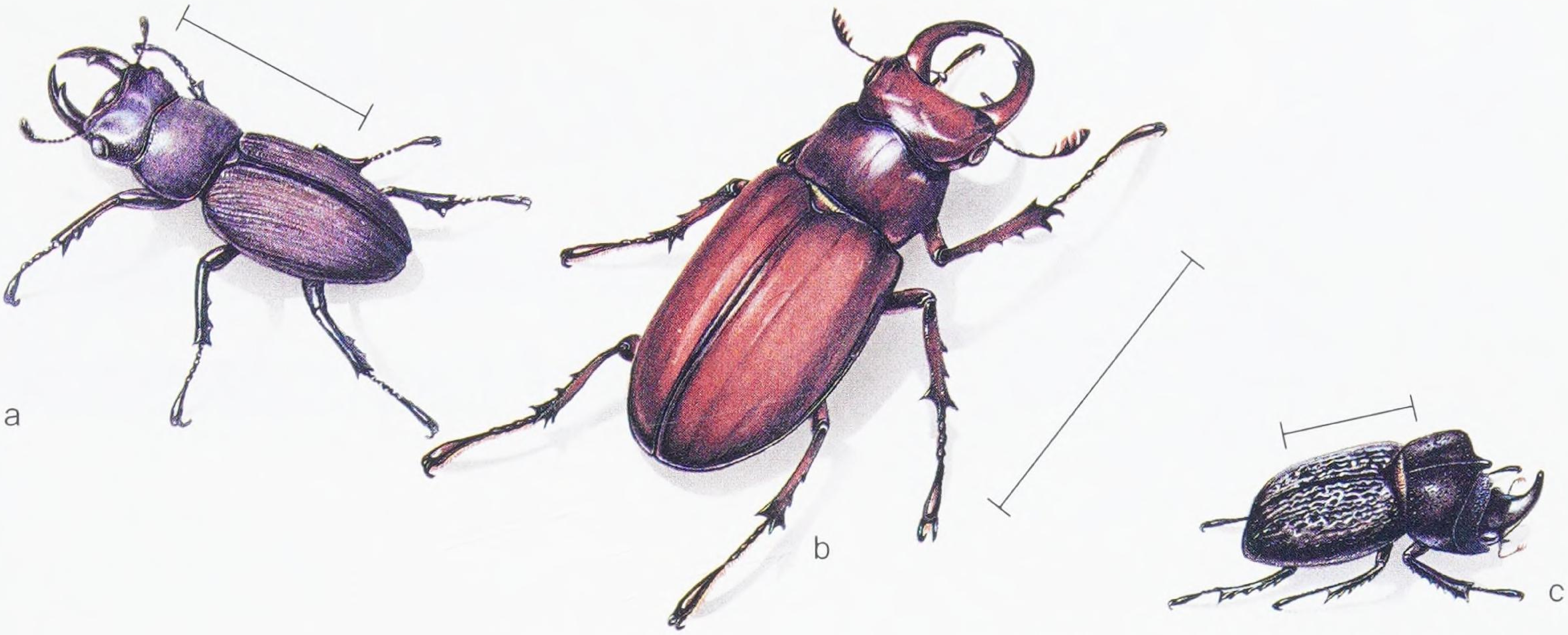


Figure 7-11. Each of these beetles is a different species. The line next to each drawing is a scale that shows what the actual length of each beetle is. *Measure* each to determine its length in mm.

Let's identify the stag beetle in Table 7-2. Start at Step 1 of the key. Your beetle is much longer than 20 mm, so you go to Step 2. The beetle is dark brown to black, so you skip Step 3 and go to Step 4. Your beetle is about 50 mm long with overlapping mouth parts, so you choose 4b. The dichotomous key tells you that the insect is *Lucanus elaphus,* commonly called an elephant stag beetle or giant stag beetle.

There are many kinds of field guides available. There are field guides to plants, mushrooms, fish, butterflies, and every other kind of organism. You could find the names of species from all around the world by following the descriptions in the proper dichotomous key.

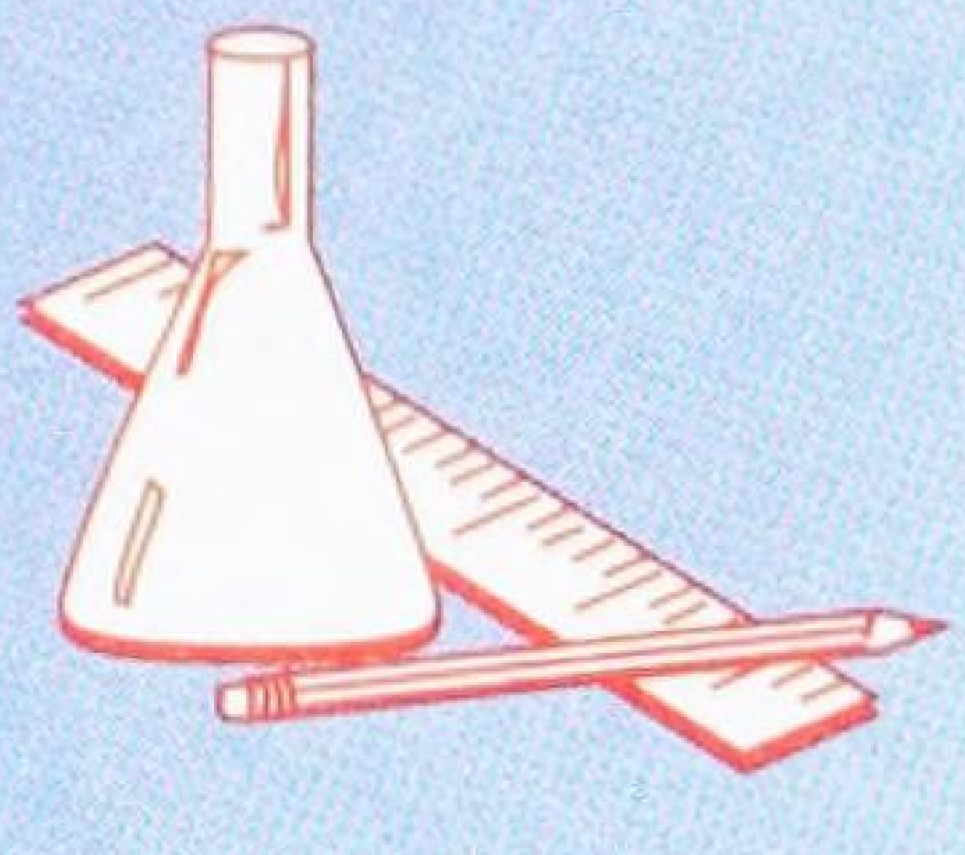
SECTION REVIEW

1. List four reasons biologists use scientific names instead of common names in their communications.
2. Why can common names cause confusion?
3. What is the function of a dichotomous key?
4. **Apply:** Why would you infer that two species that look similar share a common evolutionary history?
5. **Connect to Earth Science:** Find out what Mohs' Mineral scale is.

Classifying

Skill Builder

Classify the beetles marked a, b, and c in Figure 7-11, using the dichotomous key in Table 7-2. If you need help, refer to Classifying in the **Skill Handbook** on page 680.



ACTIVITY 7-2

Using a Dichotomous Key

Problem: *How can a dichotomous key be used to identify jays?*

Materials

- paper and pencil

Procedure

1. Look at the jays pictured below.
2. Begin with Step 1 of the Dichotomous Key to Jays of North America. Use the key to *identify* the bird below labeled A.
3. On your paper, make a data table like the one shown. Write the common name and scientific name for the jay.
4. Use the same procedure to *identify* the species of jay labeled B.

Data and Observations

Jay	Scientific Name	Common Name
A		
B		

Analyze

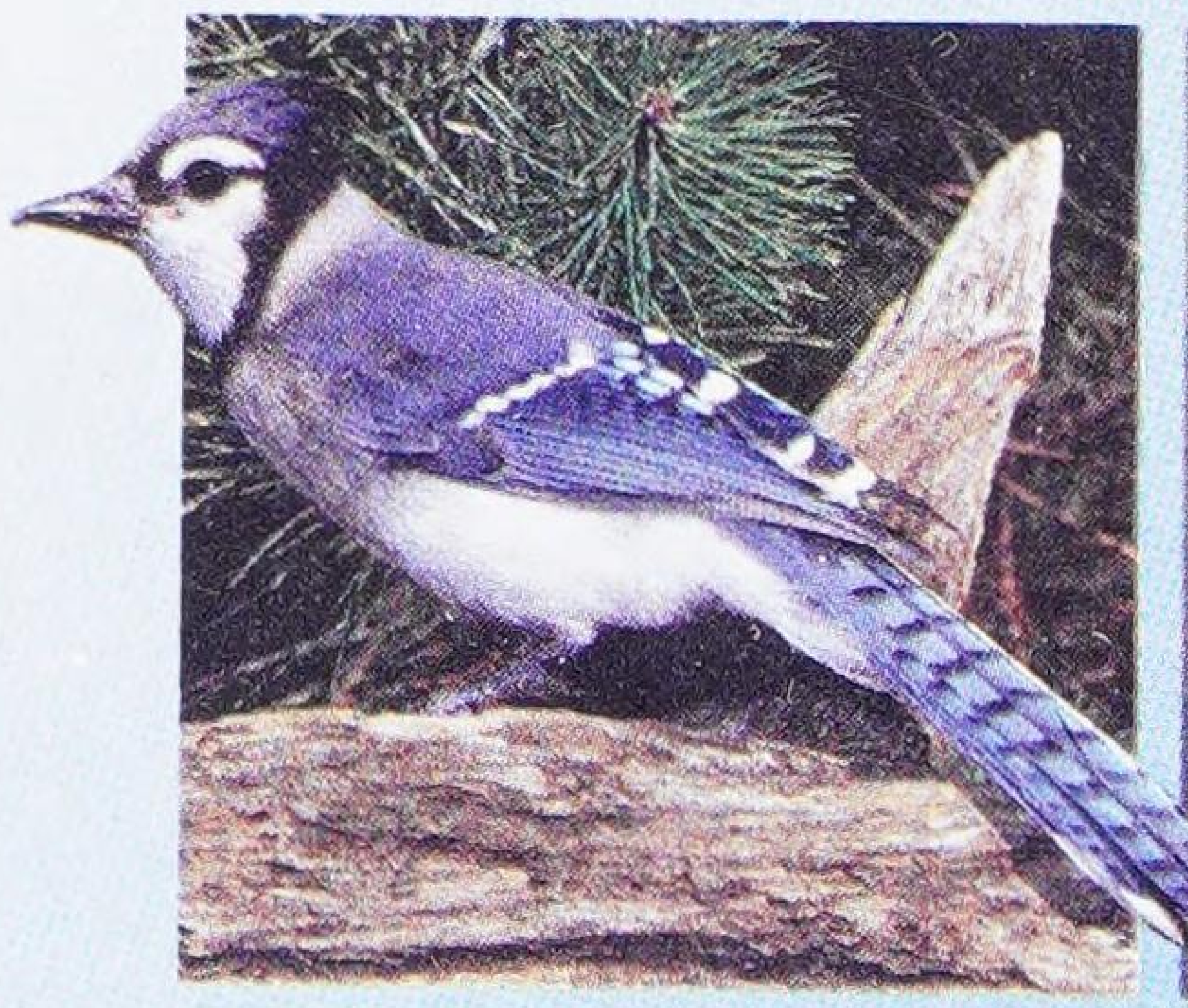
1. According to the key, how many species of jay are in North America?
2. How many genera (more than one genus) can be identified with this key?

Conclude and Apply

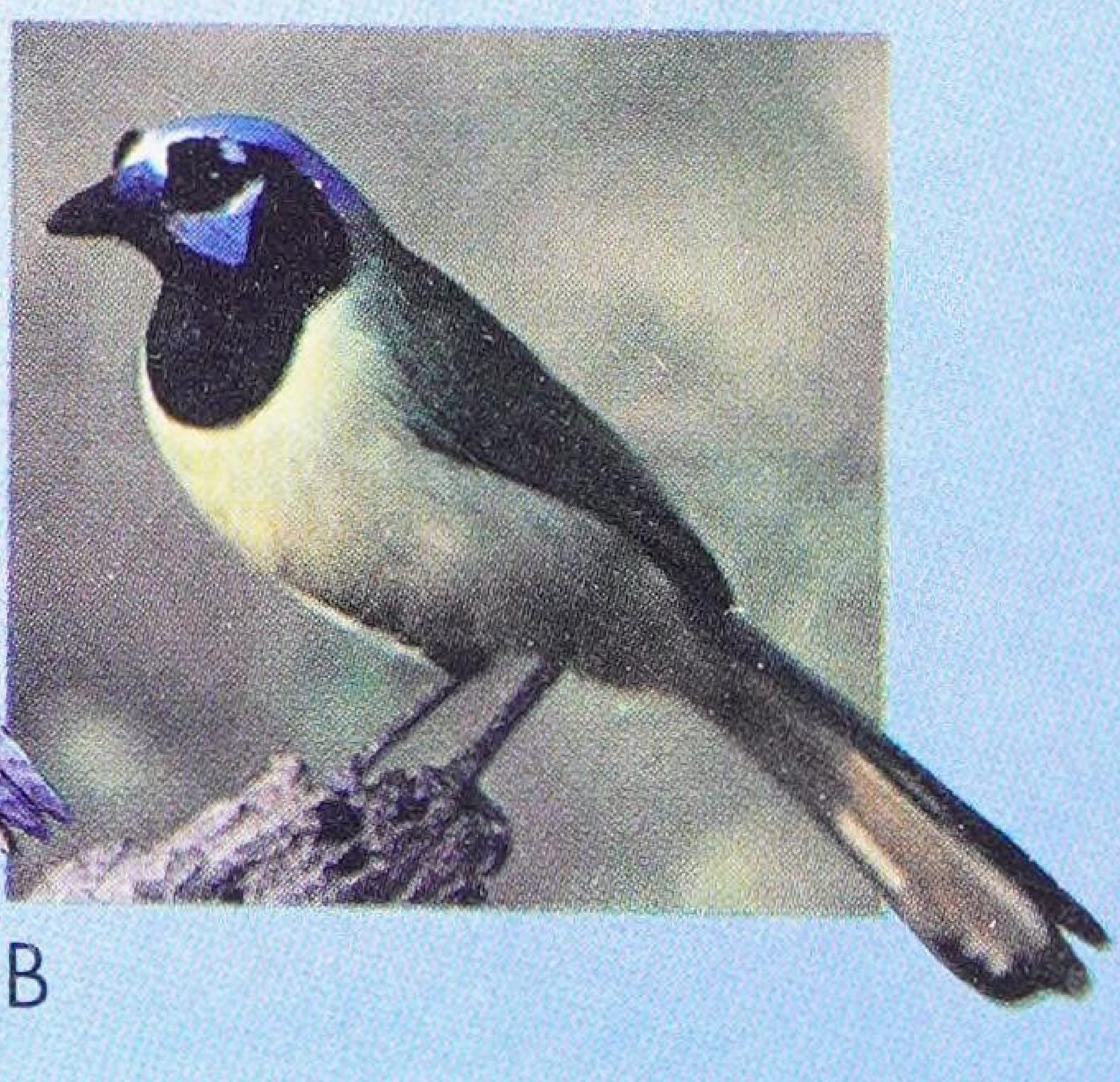
3. How do you know that this key doesn't contain all the species of jays in the world?
4. Why couldn't you be successful in identifying a robin using this key?
5. Why wouldn't it be a good idea to begin in the middle of a key, instead of with the first step?

KEY TO JAYS OF NORTH AMERICA

1a If the jay has a crest on the head, go to Step 2.
1b If the jay has no crest, go to Step 3.
2a If the jay's crest and upper body are mostly blue, it is a blue jay, *Cyanocitta cristata*.
2b If the jay's crest and upper body are brown or gray, it is a stellar's jay, *Cyanocitta stelleri*.
3a If the jay is mostly blue, go to Step 4.
3b If the jay has little or no blue, go to Step 6.
4a If the jay has a white throat outlined in blue, it is a scrub jay, *Aphelocoma coerulescens*.
4b If the throat is not white go to Step 5.
5a If the jay has a dark eye mask and gray breast, it is a gray-breasted jay, *Aphelocoma ultramarinus*.
5b If the jay has no eye mask and has a gray breast, it is a pinyon jay, *Gymnorhinus cyanocephalus*.
6a If the jay is mostly gray and has black and white head markings, it is a gray jay, *Perisoreus canadensis*.
6b If the jay is not gray, go to Step 7.
7a If the jay has a brilliant green body with some blue on the head, it is a green jay, *Cyanocorax yncas*.
7b If the jay has a plain brown body, it is a brown jay, *Cyanocorax moria*.



A



B

CHAPTER REVIEW

SUMMARY

7-1: What Is Classification?

1. To *classify* means to group ideas, information, or objects based on similarities. Taxonomy is the study of grouping and naming organisms.

2. Aristotle was the first to develop a system to classify organisms.

3. Linnaeus developed a two-word system to name organisms.

4. Binomial nomenclature is a two-word naming system that gives every organism its own scientific name.

7-2: Modern Classification

1. The five kingdoms of living things are Monera, Protist, Fungi, Plant, and Animal.

2. Monerans, such as bacteria and cyanobacteria, are single-celled prokaryotes. The Kingdom Protist contains a variety of single-celled and many-celled eukaryotic organisms. Fungi are eukaryotic, many-celled organisms that can't make their own food. Plants and animals are both eukaryotic, many-celled organisms. Plants can make their own food, animals can't.

3. Organisms without an organized nucleus and cell organelles are prokaryotes. Eukaryotes have a nucleus and organelles.

4. Organisms are classified into seven categories. They are kingdom, phylum, class, order, family, genus, and species. The genus and species names a specific organism.

7-3: Science and Society: The Rain Forest Crisis

1. Many species of plants and animals are lost due to the deforestation of rain forests. The world's atmosphere may be damaged by the loss of the oxygen-producing trees.

2. Native people depend on rain forests for timber and farming to survive.

7-4: Identifying Organisms

1. Scientific names help scientists communicate. They also allow organisms with similar evolutionary histories to be classified together. Scientific names give descriptive information about the species and allow information about organisms to be organized.

2. Dichotomous keys are used to identify specific organisms.

3. Dichotomous keys are made up of steps of paired descriptions.

KEY SCIENCE WORDS

a. **binomial nomenclature**
b. **classes**
c. **classify**
d. **dichotomous keys**
e. **division**
f. **families**
g. **genus**
h. **kingdom**
i. **orders**
j. **phylogeny**
k. **phylum**
l. **species**
m. **species diversity**
n. **taxonomy**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. to put similar organisms in groups
2. a group of similar species
3. the science of classification
4. system of naming organisms with two names
5. evolutionary history of organisms
6. tools for identifying organisms
7. subdivisions of a class
8. largest group within the Plant kingdom
9. variety of plants and animals
10. the second of an organism's scientific names

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. The group with the most members is a ______.
   a. family c. genus
   b. kingdom d. order
2. Organisms that are the most similar belong in a ______.
   a. family c. genus
   b. class d. species
3. The most complex organisms are ______.
   a. animals c. plants
   b. monerans d. protists
4. The closest relative of *Canis lupus* is ______.
   a. *Quercus alba* c. *Felis tigris*
   b. *Equus zebra* d. *Canis familiaris*
5. The scientific name is written as ______.
   a. *Genus Species* c. genus Species
   b. genus species d. *Genus species*
6. The kingdom bacteria belong to is ______.
   a. Animal c. Monera
   b. Fungi d. Plant
7. The ______ do not have eukaryotic cells.
   a. animals c. monerans
   b. fungi d. plants
8. The simplest eukaryotes are ______.
   a. animals c. monerans
   b. fungi d. protists
9. Trees and flowers are ______.
   a. animals c. monerans
   b. plants d. protists
10. Cells without an organized nucleus are ______.
    a. eukaryotes c. species
    b. phylogeny d. prokaryotes

USING LAB SKILLS

11. Make an events chain to explain how the jays in the activity on page 170 were identified. For additional help, turn to Concept Mapping in the Skill Handbook on page 689.
12. Using the information in Table 7-1 on page 162, make a dichotomous key to *identify* the kingdoms of all living things. Begin your key with:
    1a If the organism has eukaryotic cells, go to Step 2.
    1b If the organism has prokaryotic cells, it is a member of Kingdom Monera.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Two organisms of a family also belong to what other same classification groups?
14. How do embryology and similar structures help classify organisms?
15. Why is it important to maintain the species diversity found in tropical rain forests?
16. Members of Kingdom Protist are often called "misfits." Can you explain why?

Gulfweed— A Protist

APPLY

17. Explain what binomial nomenclature is, and why it is important to scientists.

18. Name each of the five kingdoms, and *identify* a member of each kingdom.

19. Write a short dichotomous key to identify the members of your family. Use such things as sex, hair color, eye color, and weight in your key. Each individual's first and last name will make up the person's genus and species.

20. Discuss the relationship between tigers and lions, members of *Felis.*

21. Scientific names often describe a characteristic of the organism. What does *Lathyrus odoratus* tell you about a sweet pea?

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Comparing and Contrasting:** Compare the number and variety of organisms in a kingdom and genus.
2. **Classifying:** Use the Key to Jays of North America on page 170 to identify the birds below.
3. **Observing and Inferring:** You observe an organism you don't know. How would you go about determining its classification?
4. **Making and Using Graphs:** Make a pie graph to show the number of species in each kingdom listed in the table below.

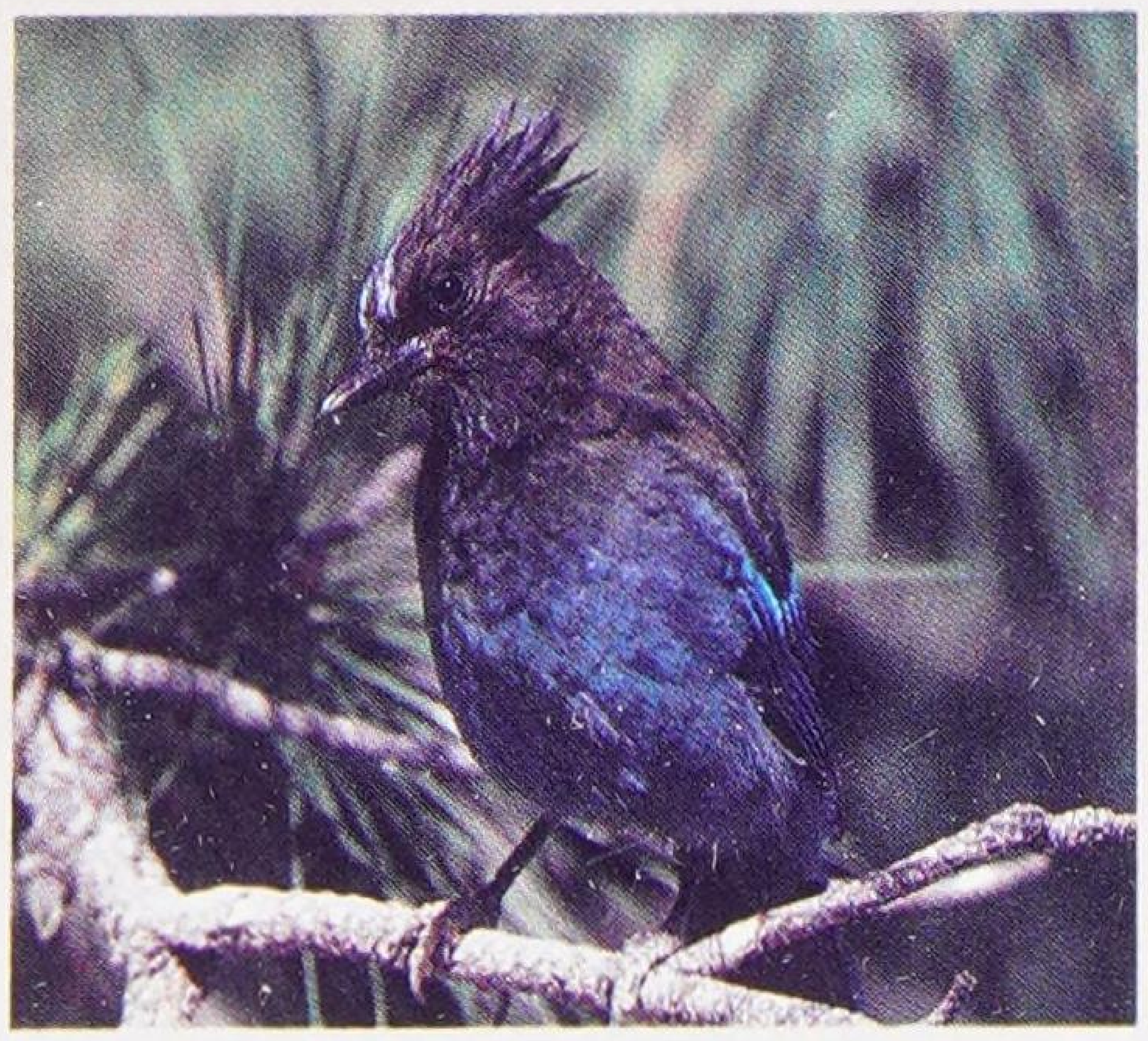
Kingdom	Number of Species
Moneran	4 000
Protist	51 000
Fungi	100 000
Plant	285 000
Animal	1 million

5. **Concept Mapping:** Starting with Aristotle, use information in Sections 7-1 and 7-2 to make an events chain concept map to show events leading to modern classification.

PROJECTS

1. Make a poster of the five kingdoms. Draw organisms found in each kingdom, or make a collage using photographs.
2. As a class, make a local field guide for the school grounds or a nearby park. Draw maps and give the location of plants. Identify the plants and animals by common name and as many scientific names as you can.

a



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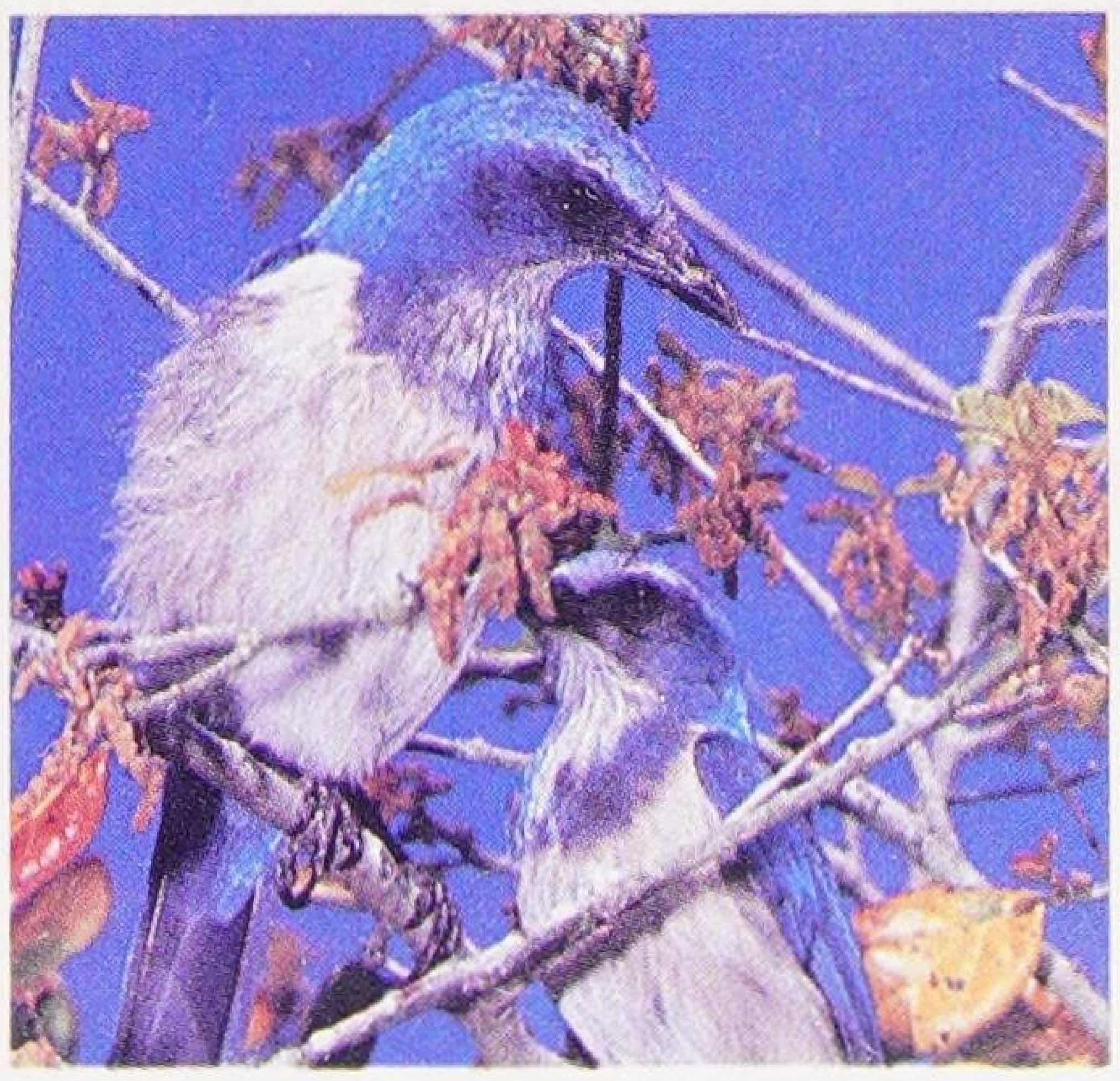

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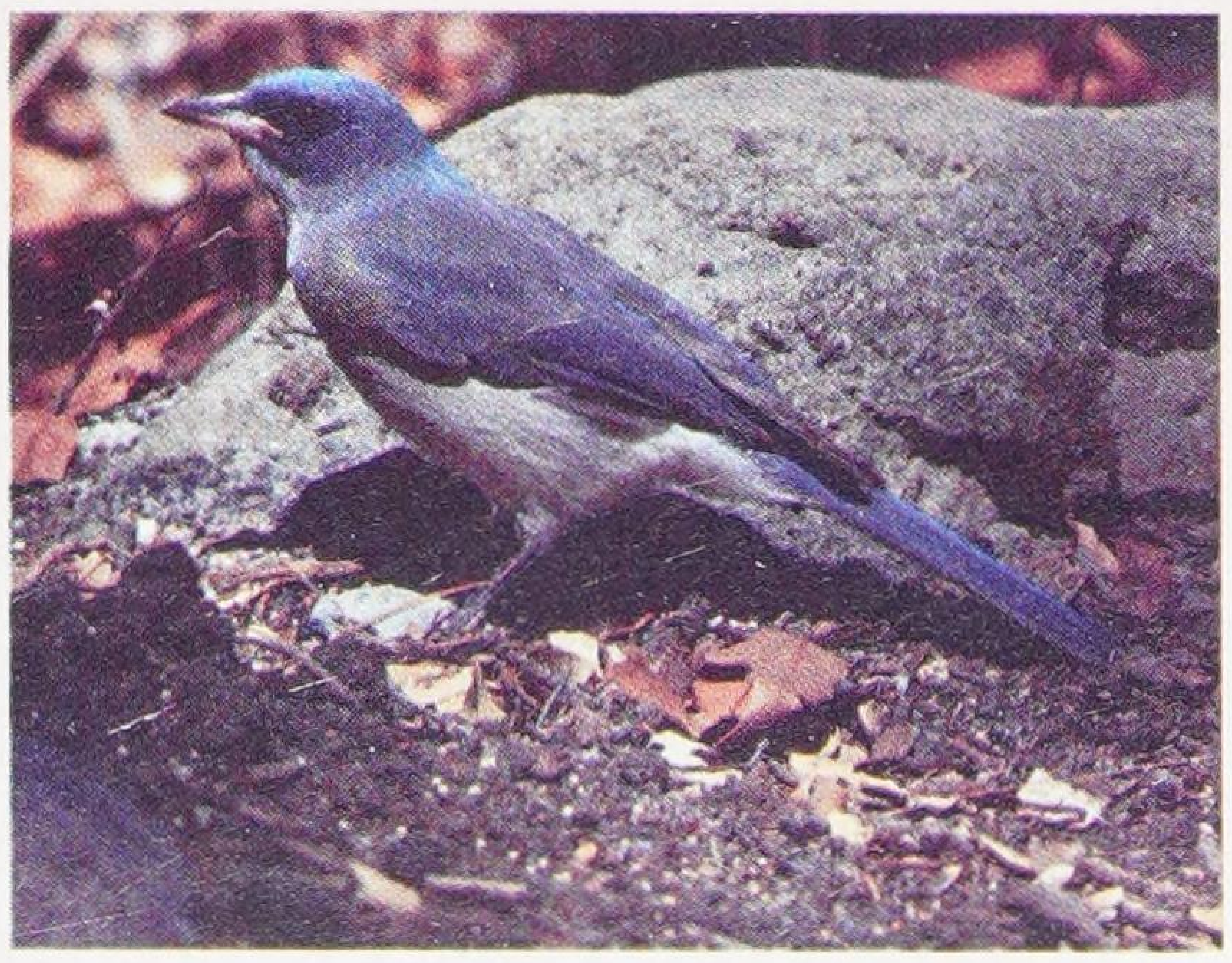


UNIT 2

GLOBAL CONNECTIONS

Heredity and Evolution

In this unit, you have studied the principles and importance of heredity and evolution. Now see how heredity and evolution influence people, places, and events throughout the world.

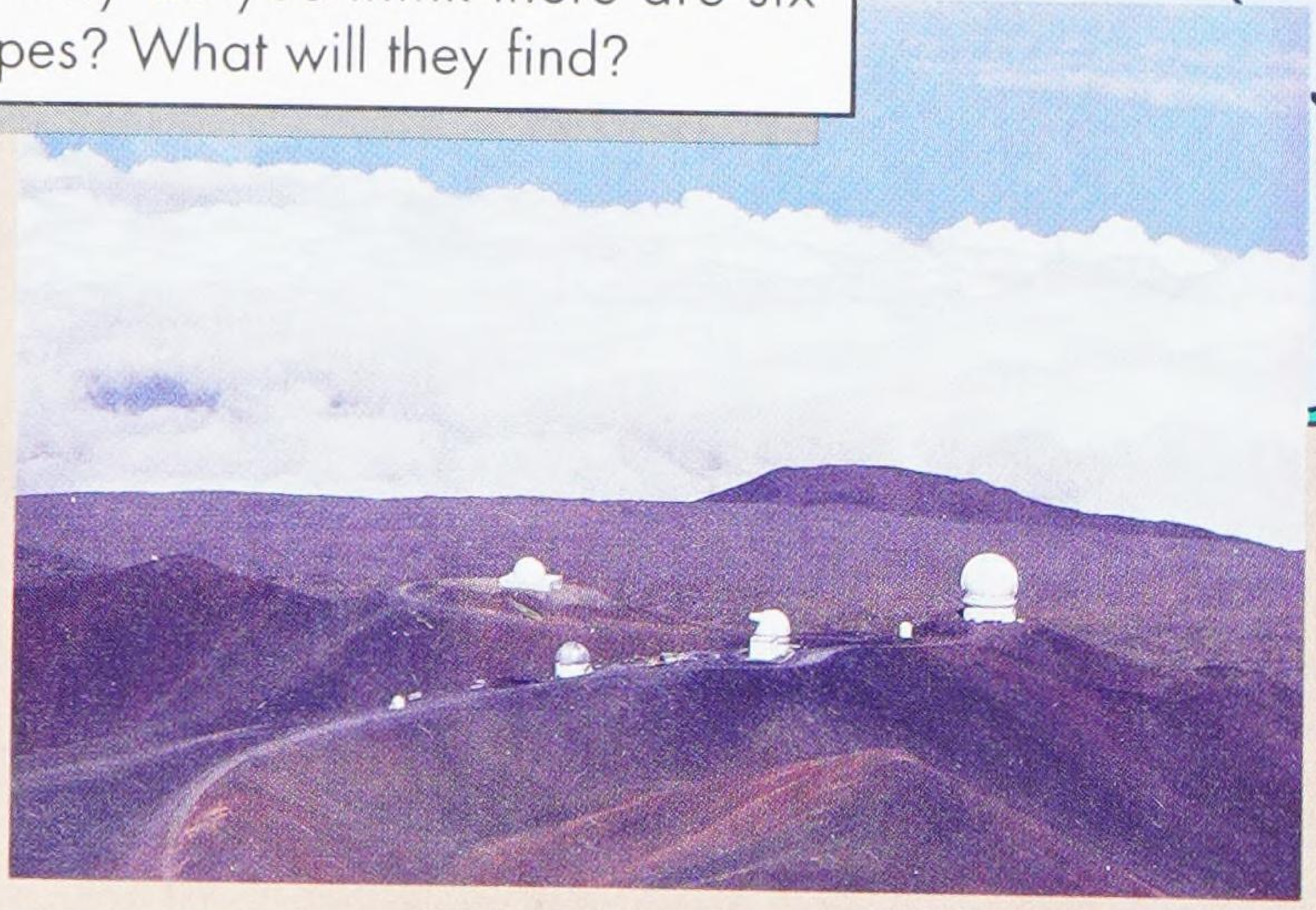
120°
60°
60°
30°
0°

ASTRONOMY

LOOKING FOR THE BIG BANG

Mauna Kea, Hawaii

Fourteen thousand feet above the Pacific Ocean, at the Mauna Kea Observatory, six telescopes search the night skies to learn more about the origin of the universe. Why do you think there are six telescopes? What will they find?

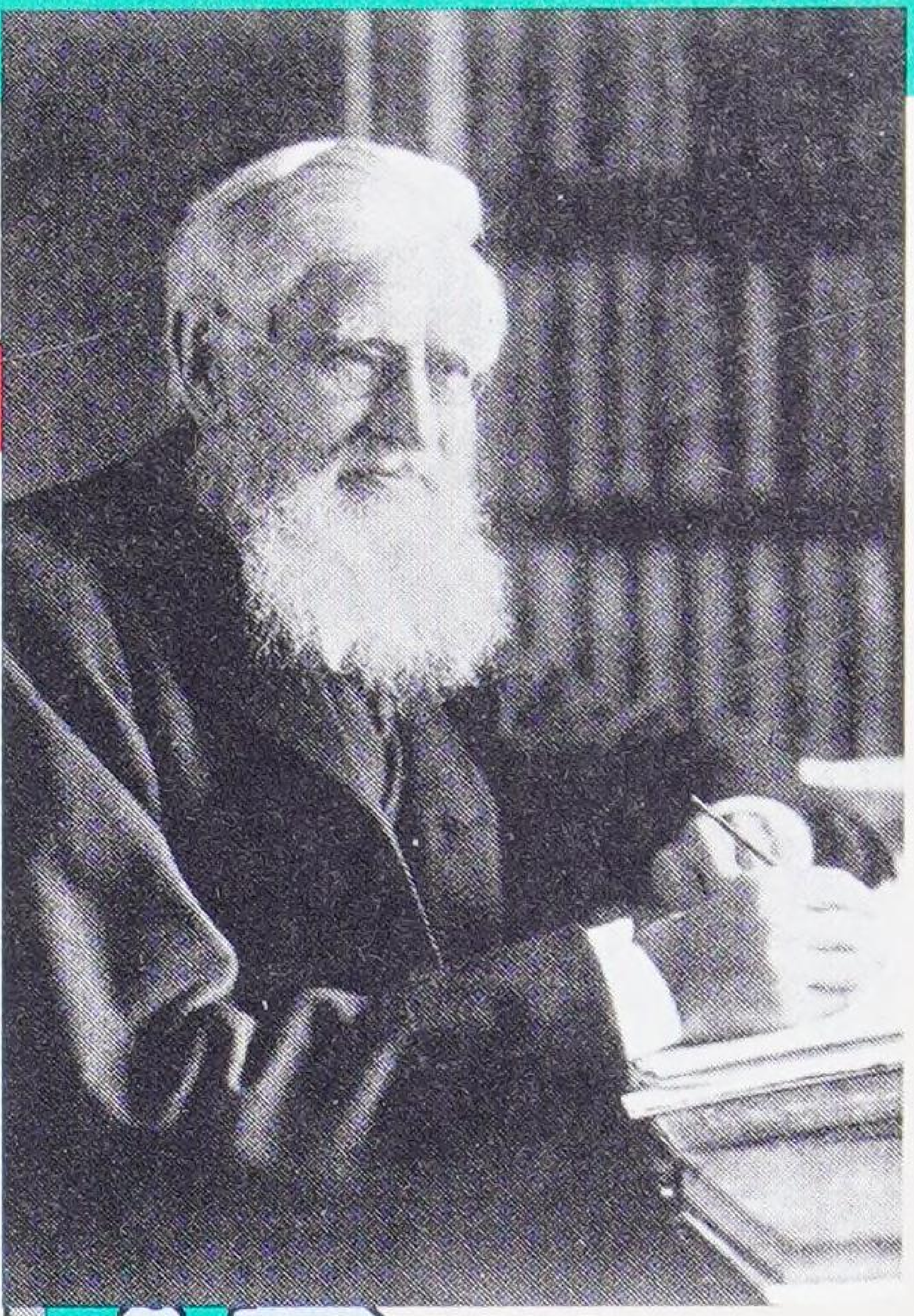


BIOLOGY

MYSTERY OF THE JUMPING GENE

Cold Spring Harbor, New York

Geneticist Barbara McClintock puzzled over the different colors of Indian corn husks. Through her studies, she learned that genes often change their positions on a single chromosome. She called them "jumping genes." Why are genes important?



HISTORY

AN IDEA WHOSE TIME HAD COME

Monmouth, England

Alfred Russel Wallace, a naturalist and philosopher, developed a theory of evolution by natural selection separately from Charles Darwin. His ideas and Darwin's were presented together at a scientific meeting in London in 1858. Why do you think Alfred Wallace is not as well known as Darwin?

BIOLOGY

A LIVING FOSSIL

The Republic of Comoros

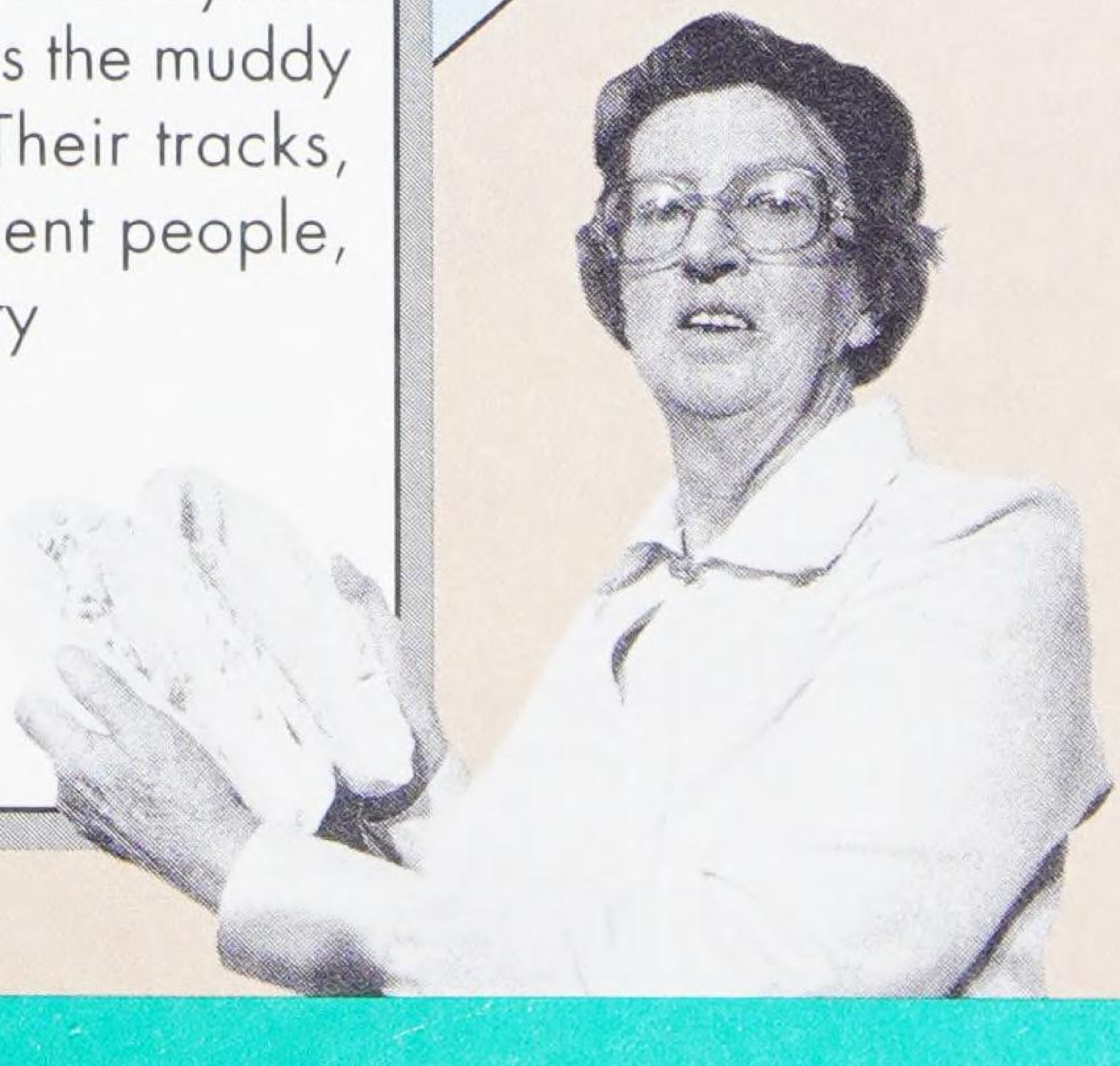
The Indian Ocean, off the east coast of Africa near Madagascar, teems with life. It was there that a "living fossil" called the coelacanth was discovered by Melanie Courtenay-Latinerin. Find out why the discovery of a coelacanth is important to science.

PALEONTOLOGY

FOOTPRINTS IN TIME

Olduvai Gorge, Tanzania

Three million, six hundred thousand years ago, someone walked across the muddy southern Serengeti Plains. Their tracks, and other evidence of ancient people, have been discovered by Mary Leakey and her family. The tracks show that ancient people walked erect. What would be important about walking erect?



CAREERS

CHROMOSOMES OF NORMAL MA
SHOWING BOTH X&Y CHROM

GENETIC COUNSELOR

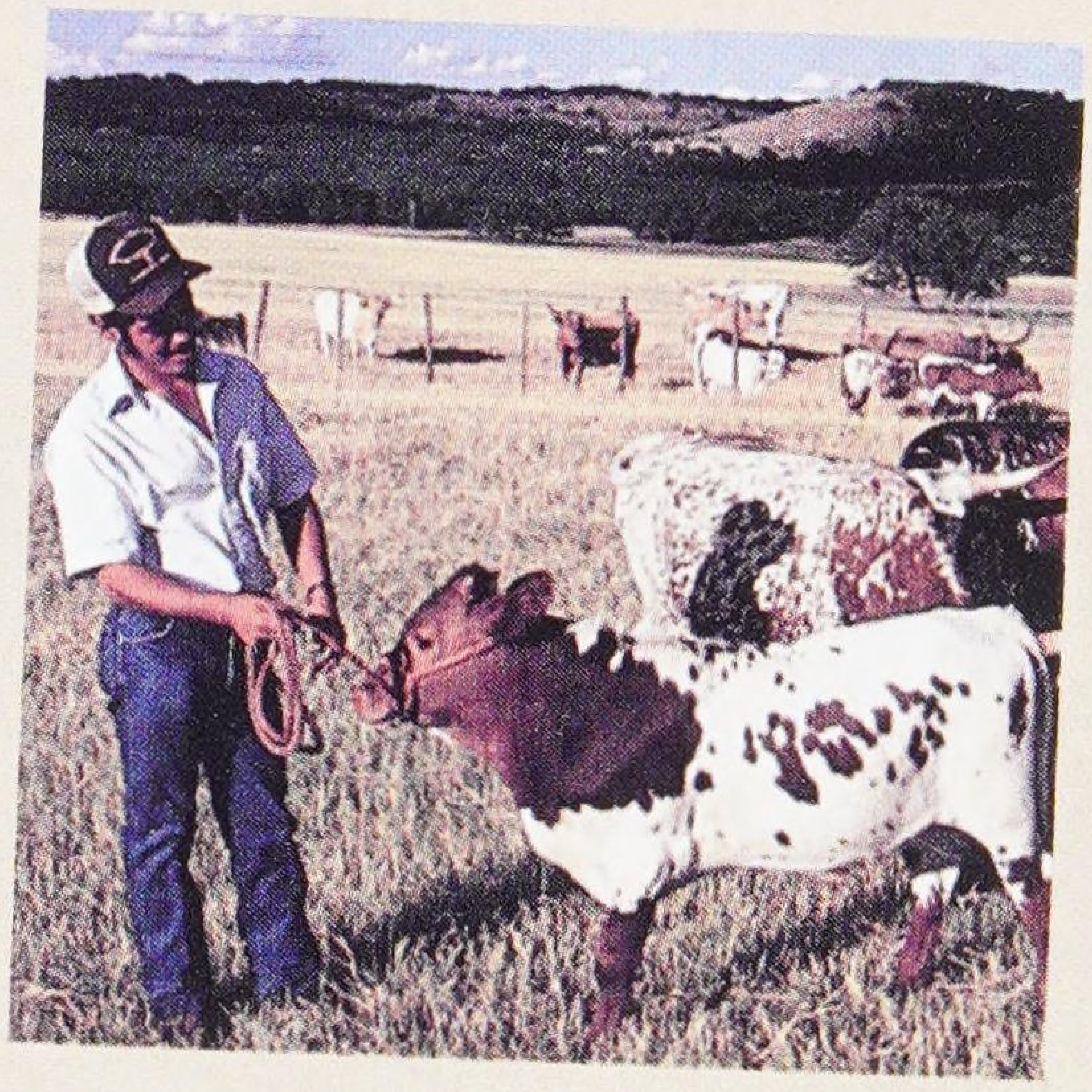
Genetic counselors work in the field of medicine. They do genetic testing to help doctors understand the genetic background of a patient. Knowing a patient's genetic background can help doctors make a diagnosis or predict the risks of an inherited disease occurring. For instance, the risk for certain types of breast cancer can show in a person's genes. The risk of bearing a child with a genetic illness worries many people. With genetic testing, they can learn whether they have a good chance of having a healthy child. A person who is interested in becoming a genetic counselor should have a background in science, especially biology and genetics. A genetic counselor must have a master's degree and be certified by one of the health accrediting agencies. He or she should enjoy working with people.

For Additional Information

Contact the American Institute of Biological Sciences, Office of Career Service, 730 11th St. NW., Washington, DC 20001-4584

UNIT READINGS

- ▶"The Telltale Gene." *Consumer Reports*, July, 1990, pp. 483-488.
- ▶"An Earlier Cancer Warning." *Newsweek*, Dec. 31, 1990, p. 68.



FARMER

Farmers who raise animals such as cattle or hogs or horses, keep records of the health and inheritance of these animals. By breeding the best of their animals, they improve their livestock. Most farmers are also aware of the benefits of genetically improved crop plants such as corn and soybeans. Many farmers learn farming through work on the family farm. Farmers spend much of their time working outdoors. They need to be in good physical health, because farm work involves hard physical labor. Because farming is changing, many farmers attend four-year college programs to learn advanced farming methods and business management. Organizations such as the National Farm Bureau and County Extension Agencies offer programs on livestock and crop production.

For Additional Information

Contact the National FFA Organization, Box 15160, 5632 Mt. Vernon Memorial Hwy., Alexandria, VA 22309; or the American Farm Bureau Federation, 225 Touhy Ave., Park Ridge, IL 60068.

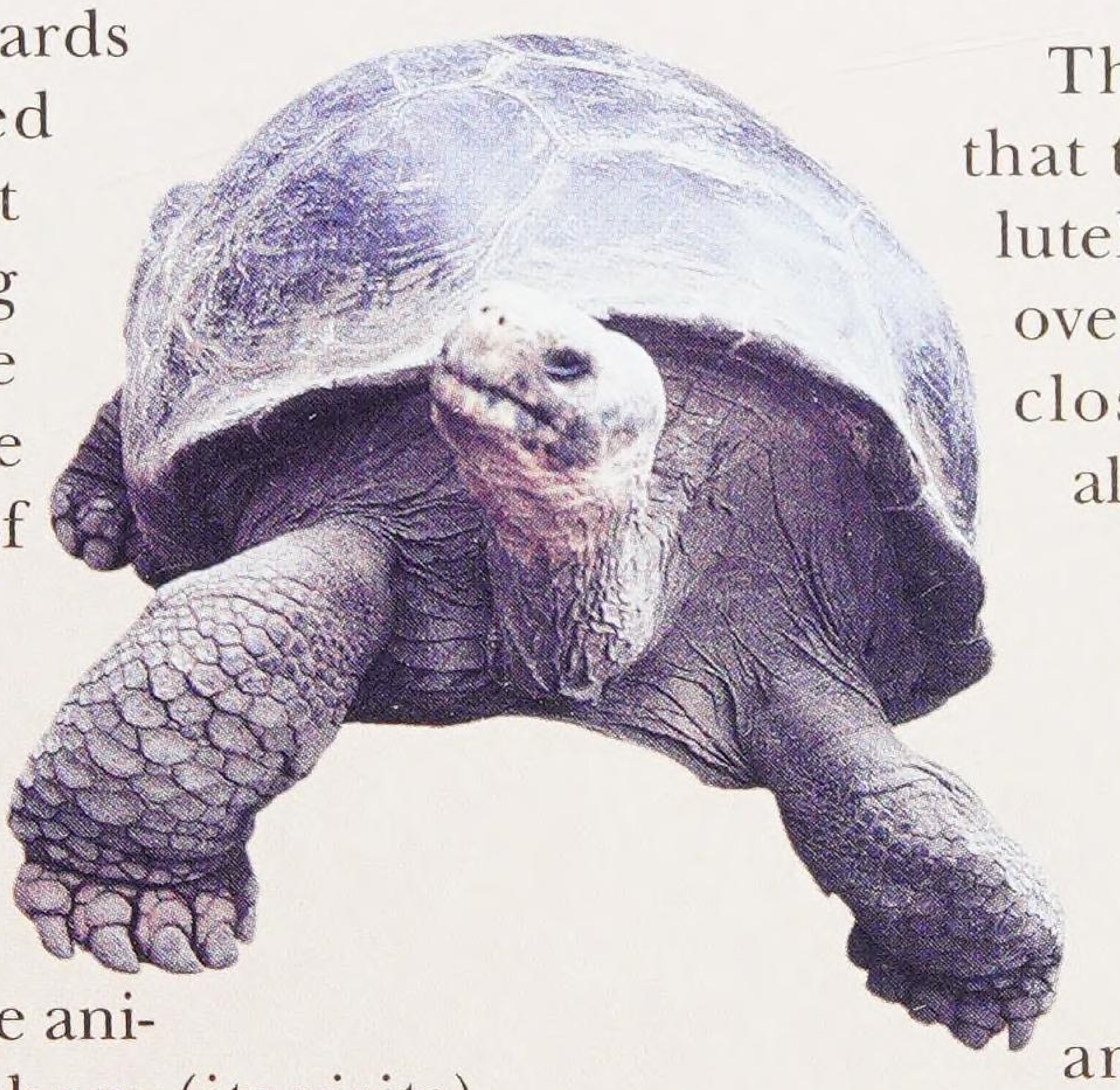
SCIENCE & LITERATURE

The Voyage of the Beagle

by Charles Darwin

The following passage recounts Darwin's observations of tortoises on the Galapagos Islands in September 1835.

The tortoise is very fond of water, drinking large quantities, and wallowing in the mud. The larger islands alone possess springs. Near the springs it was a curious spectacle to behold many of these huge creatures, one set eagerly traveling onwards with their outstretched necks, and another set returning, after having drunk their fill. When the tortoise arrives at the spring, quite regardless of any spectator, he buries his head in the water above his eyes, and greedily swallows great mouthfulls, at the rate of about ten in a minute. The animal probably regulates them (its visits) according to the nature of the food on which it has lived. It is, however, certain, that tortoises can subsist even on these islands where there is no other water than what falls during a few rainy days in the year....



During the breeding season, when the male and female are together, the male utters a hoarse roar or bellowing, which, it is said, can be heard at the distance of more than a hundred yards. The female never uses her voice, and the male only at these times; so that when the people hear this noise, they know the two are together. They were at this time (October) laying their eggs.... The young tortoises, as soon as they are hatched, fall a prey in great numbers to the carrion-feeding buzzard. The old ones seem generally to die from accidents, as from falling down precipices: at least, several of the inhabitants told me, that they never found one dead without some evident cause.

The inhabitants believe that these animals are absolutely deaf; certainly do not overhear a person walking close behind them. I was always amused when overtaking one of these great monsters, as it was quietly pacing along, to see how suddenly, the instant I passed, it would draw in its head and legs, and uttering a deep hiss fall to the ground with a heavy sound, as if struck dead. I frequently got on their backs, and then giving a few raps on the hinder part of their shells, they would rise up and walk away, but I found it very difficult to keep my balance.

In Your Own Words

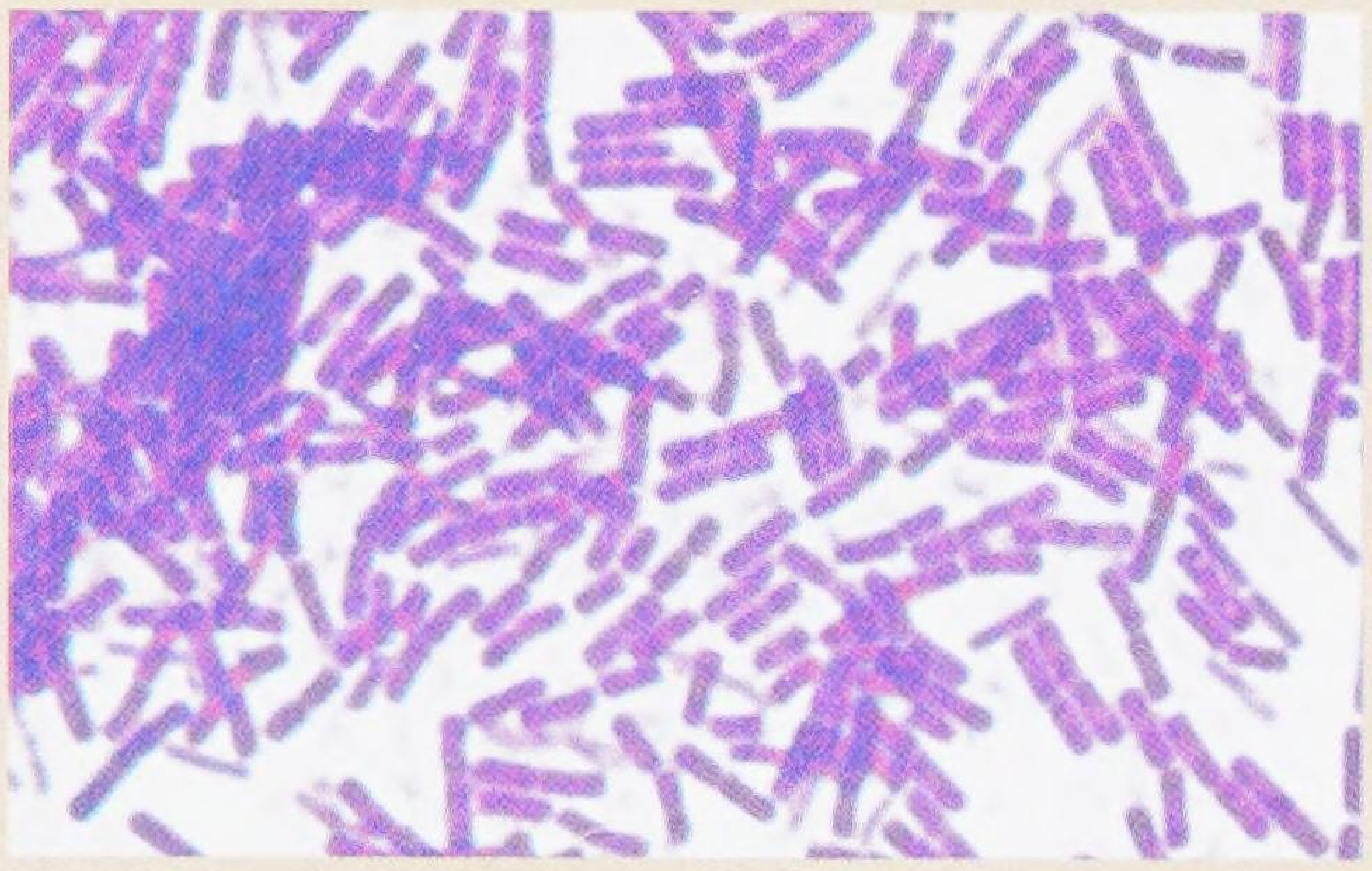
- In a brief essay, state the aspects of the tortoise's behavior that you may have found surprising.

UNIT

3 SIMPLE LIVING THINGS

What's Happening Here?

When 11 million gallons of oil spilled in Prince William Sound in Alaska, scientists scrambled for ways to clean up the beaches where much of the oil came to rest. In a treatment known as bioremediation, beaches were sprayed with fertilizer. Bacteria that lived on the beaches rapidly reproduced and began to break down the oil into carbon dioxide and water. Three weeks later, the beach was oil-free to a depth of about 30 cm. Bacteria have been used for 50 years to treat wastewater. Without these simple living things, the world would be covered with garbage, for bacteria are necessary for turning organic matter back into nutrients needed by all living things.

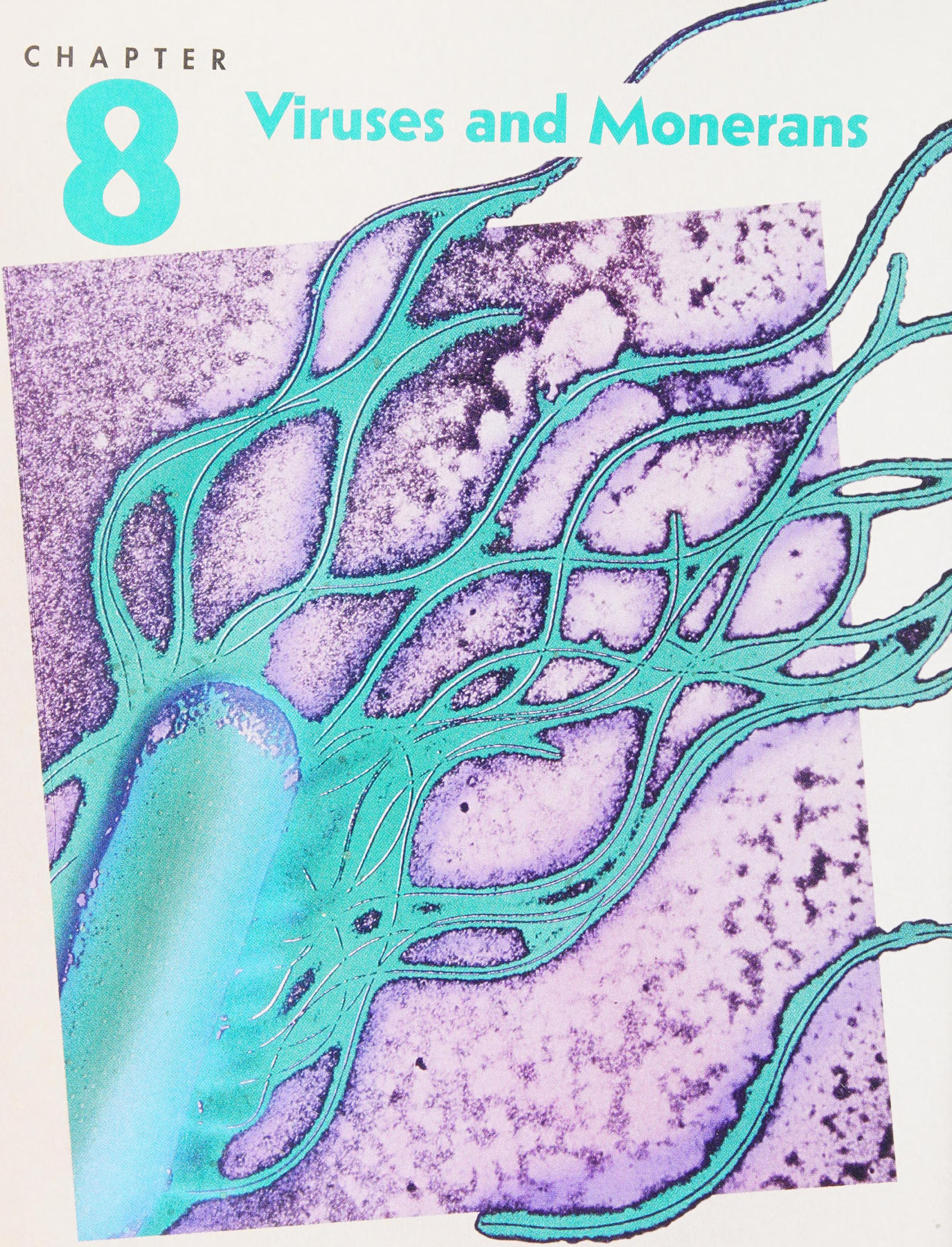


UNIT CONTENTS

Chapter 8 Viruses and Monerans
Chapter 9 Protists and Fungi

CHAPTER

8 Viruses and Monerans

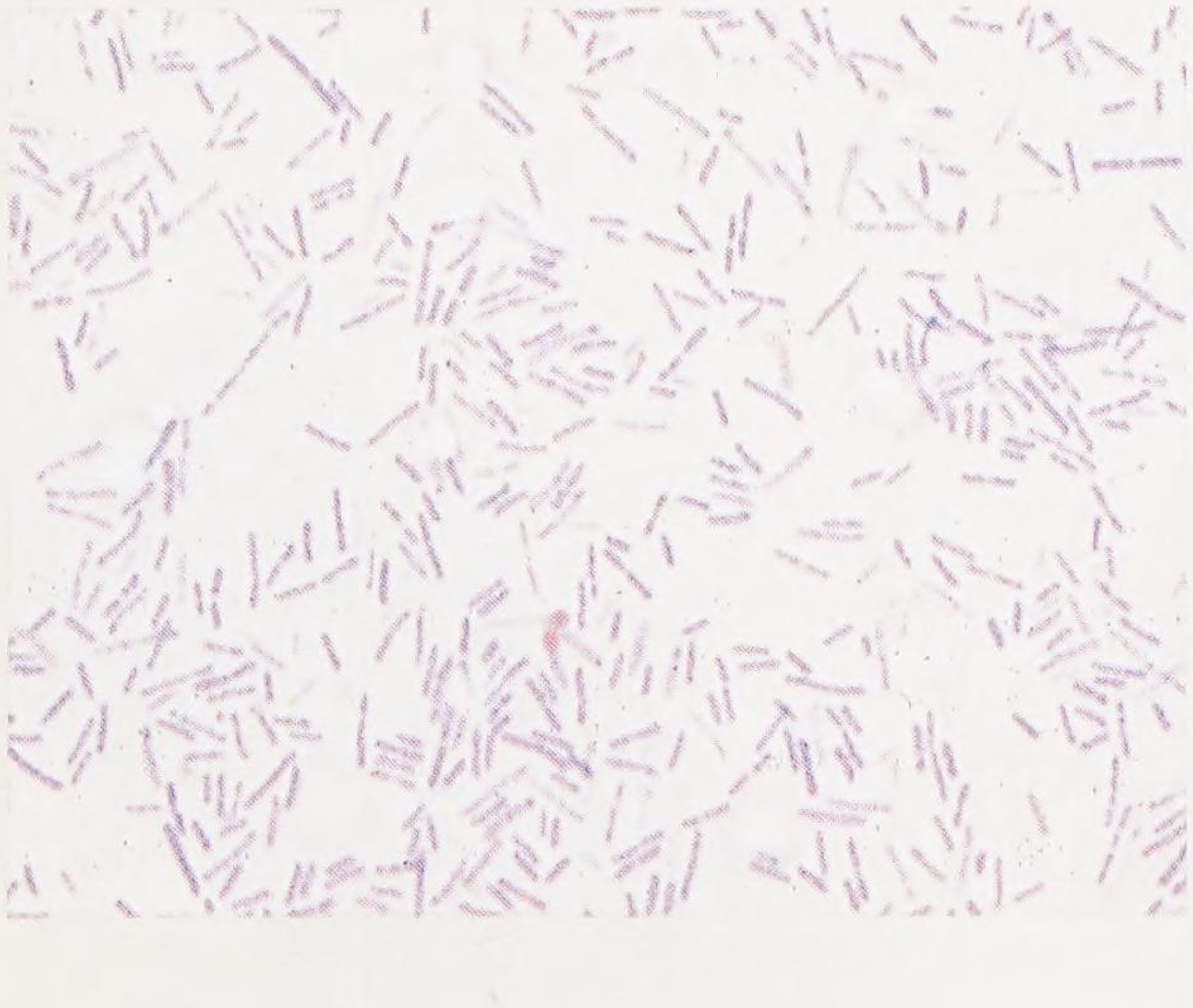


Bacteria, like the one on the opposite page that causes food poisoning, are so small that you need a microscope to see them. Viruses are even smaller. Hundreds of virus particles can fit inside a single bacterium. Isn't it amazing that something so small can make you feel so bad? Are all bacteria and viruses harmful?

FIND OUT!

Do this activity to find out what some bacteria look like.

Bacteria are used to turn milk into yogurt. In a small dish, mix a small drop of yogurt with a drop of water. Now add a drop of methylene blue dye. Methylene blue stains the bacteria so that you can see them. Put a tiny drop of the mixture on a glass slide, set a coverslip on top, and *observe* the bacteria under low and then high magnification. What do these bacteria look like?



Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 8-1 Viruses: Are They Alive?
- What Is a Virus?
- Making More Viruses
- Viruses Affect All Organisms
- Preventing Diseases
- Are There Any Good Viruses?

Section 8-2 Science and Society
The Cost of Curing a Disease
- AIDS

Section 8-3 Kingdom Monera
- What Is a Moneran?
- Bacteria
- Cyanobacteria

Section 8-4 Monerans in Your Life
- Helpful Monerans
- Harmful Monerans

Previewing Science Skills

- In the **Skill Builders,** you will hypothesize, make a concept map, and measure in SI.
- In the **Activities,** you will observe, collect and organize data, and experiment.
- In the **MINI-Labs,** you will research and experiment.

What's next?

You have just seen what some live bacteria look like. In this chapter, you will learn more about bacteria. But first you will learn about viruses, particles that are not thought of as living, but that affect you and most other organisms. Are all bacteria and viruses harmful? Is it possible that some of them are helpful? Find out.

8-1 Viruses: Are They Alive?

New Science Words

viruses
parasite
vaccine

Objectives

- Describe the structure of a virus, and explain how viruses reproduce and cause disease.
- Explain the value of vaccines.
- Describe some helpful uses of viruses.

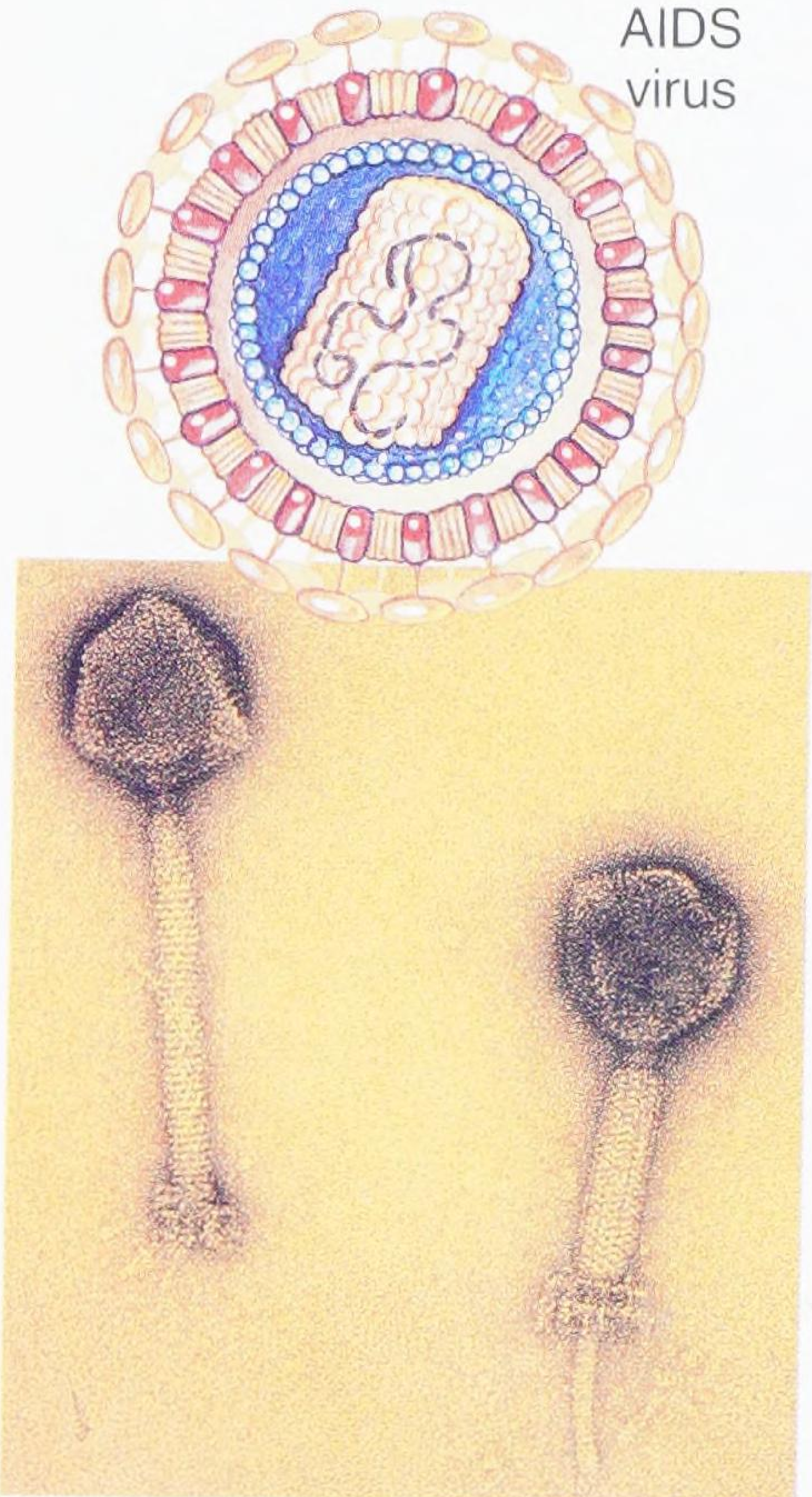
What Is a Virus?

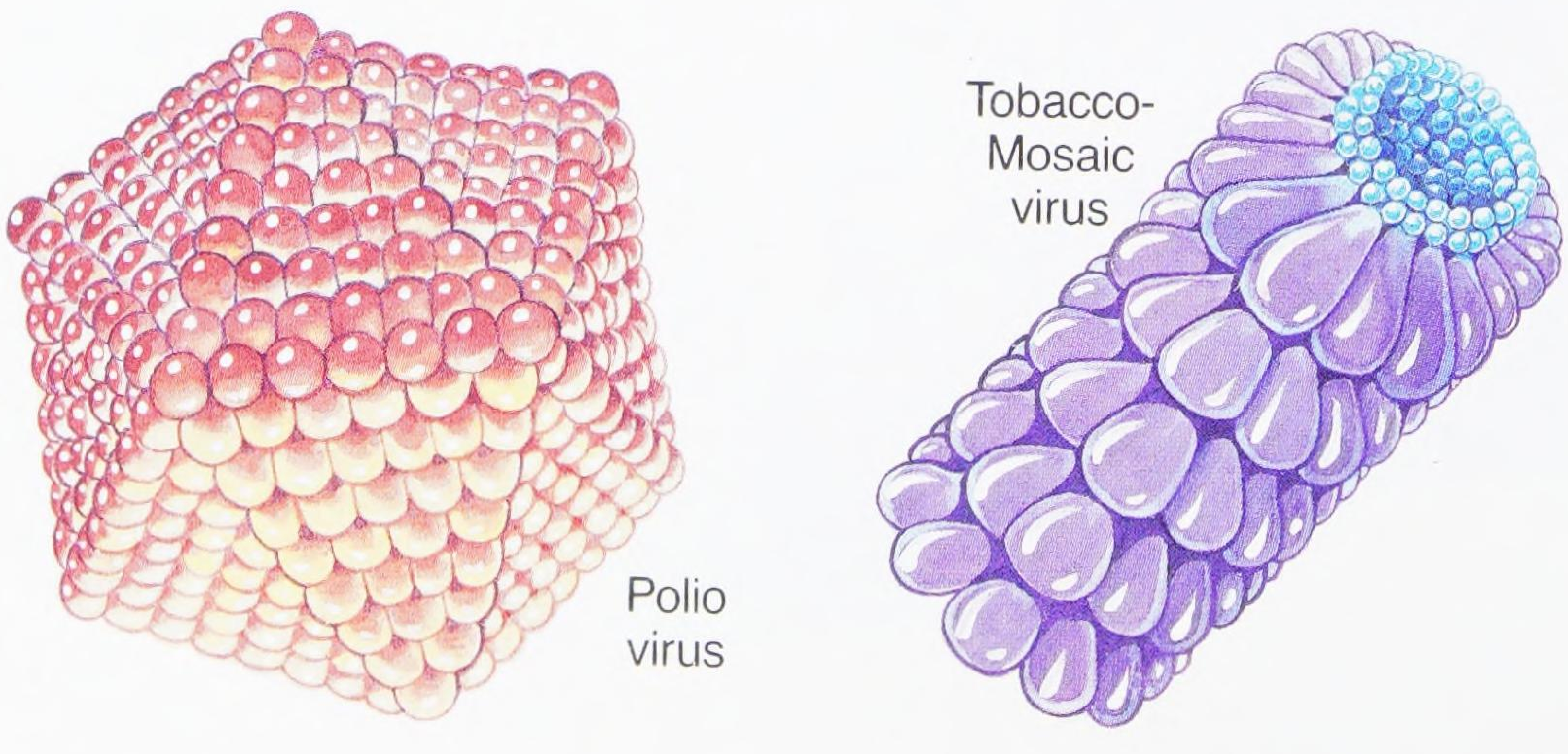
Imagine something that doesn't grow, respond, or eat, yet it can reproduce itself. This something, which appears to be neither living nor nonliving, is a virus. **Viruses** are microscopic particles made up of either a DNA or RNA core covered by a protein coat. Viruses are so small that an electron microscope is needed to see them.

Viruses are not classified in any kingdom because they are not cells. They show almost none of the characteristics of living things. Some viruses can be made into crystals and stored in a jar on a shelf for years. Then, if they are put into an organism, presto, they reproduce and cause new infections.

The classification of viruses is based on the virus' shape, the kind of nucleic acid it contains, and the kind of organism that the virus infects. The protein coat of a virus gives the particle its shape. Some viruses are many-sided and look somewhat like a soccer ball with 20 sides. Others look like rods. Some viruses have tails. Others, such as the AIDS virus, are spherical like a basketball.

Figure 8-1. Viruses have a variety of shapes. The photograph at the bottom shows virus particles that infect bacterial cells. You cannot see virus particles with a light microscope.





Making More Viruses

When most people hear the word *virus,* they relate it to a cold, AIDS, or a cold sore—anything but a pleasant experience. That's because viruses are generally destructive. They are a type of parasite. A **parasite** is anything that depends on an organism or cell to survive and may harm the thing on which it depends. As parasites, viruses depend on living cells. A virus has to be inside a cell in order to reproduce. The cell or organism that a virus depends on is called a host. Once a virus is in a host cell, the virus can act in two ways. It can either be active, or it can become part of the cell for a while.

Active Viruses

If a virus enters a cell and becomes active right away, it causes the cell to make new viruses and destroys the host cell. Figure 8-2a shows the steps an active virus takes to reproduce itself inside a bacterial cell:

1. **Attach:** A specific virus attaches to the surface of a specific bacterial cell.
2. **Invade:** The nucleic acid of the virus injects itself into the cell.
3. **Copy:** The viral nucleic acid takes control of the cell, and the cell begins to make new virus particles.
4. **Release:** The cell bursts open, and hundreds of new virus particles are released from the cell. These new viruses go on to infect other cells.

Latent Viruses

Some viruses are called latent viruses. A latent virus enters a cell and becomes part of the cell's DNA without destroying the cell or making new viruses. The viral nucleic acid becomes part of the cell's own DNA as in Figure 8-2b. As the cell divides, the virus is reproduced right along with it. Latent viruses can hide inside host cells for a long time. Then, without warning, the virus becomes active. It forms new virus particles and destroys the cell. If you have ever had a cold sore, you've experienced a virus going from the latent phase into the active phase. The painful cold sore on your lip is a sign that the virus is active. It's destroying thousands of cells in your lip. Stress factors, such as too much sun or a cold, may cause a virus to become active. When the cold sore disappears, the virus has become latent again. The virus is still in your body, you just don't realize it.

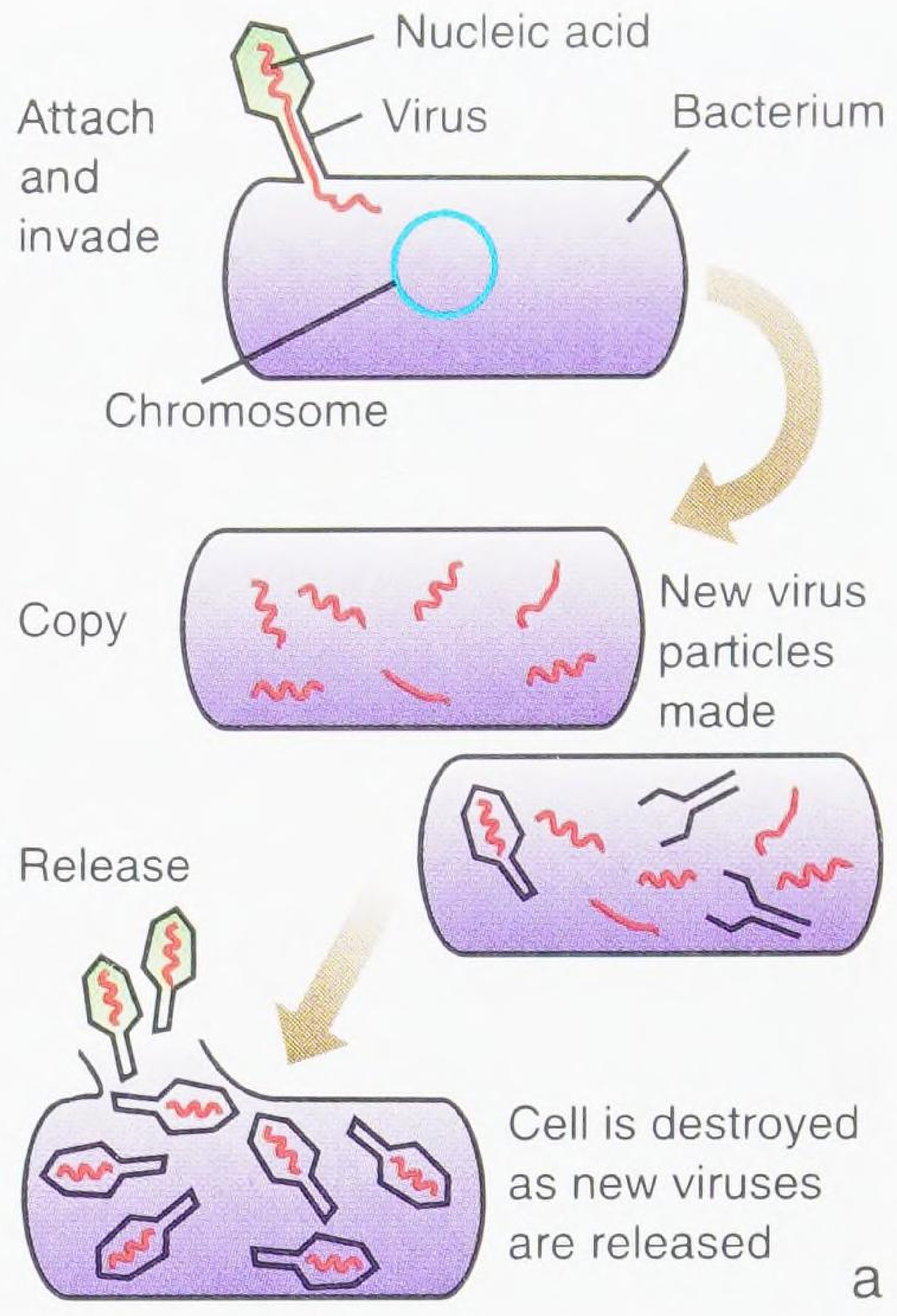
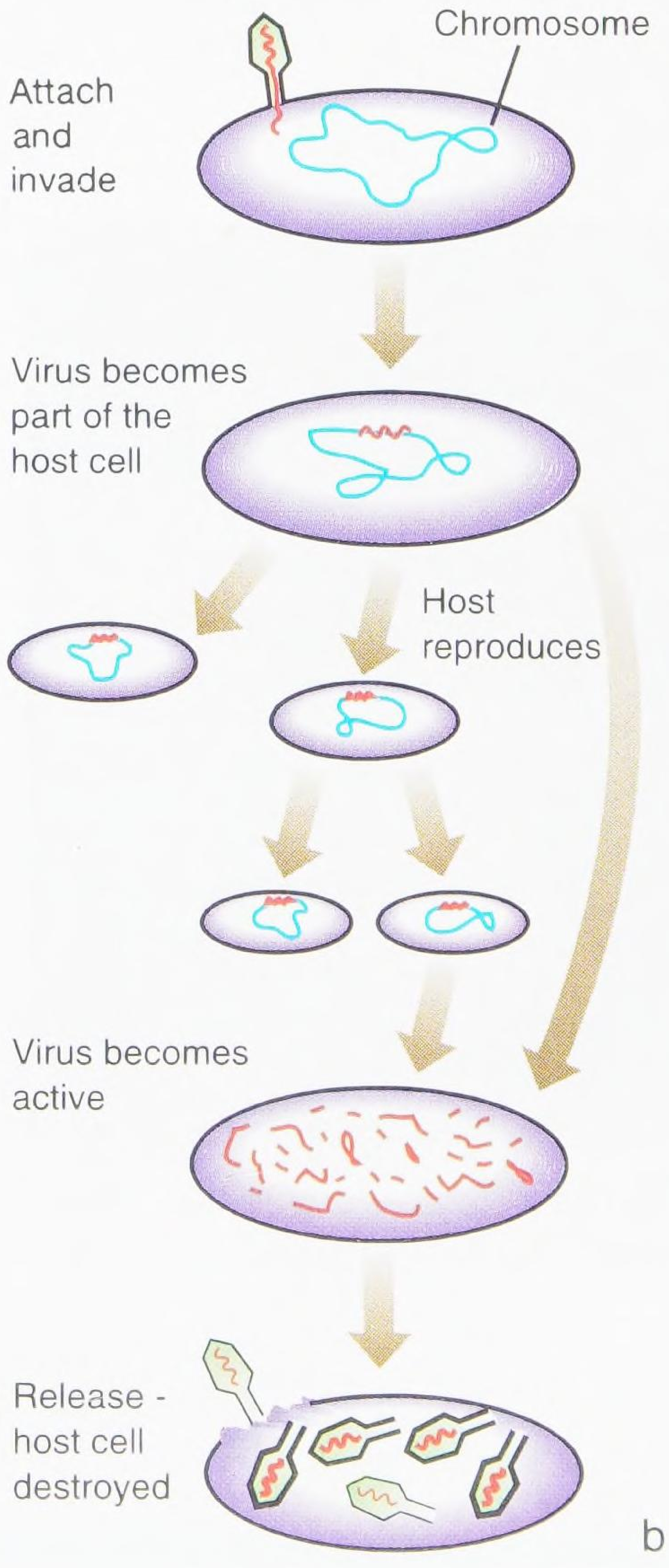

Nucleic acid
Attach and invade
Virus
Bacterium
Chromosome
Copy
New virus particles made
Release
Cell is destroyed as new viruses are released
a

Figure 8-2. An active virus reproduces and destroys the cell (a). A latent virus, below, may not destroy a cell immediately (b).


Chromosome
Attach and invade
Virus becomes part of the host cell
Host reproduces
Virus becomes active
Release - host cell destroyed
b

MINI-Lab

Is your cat vaccinated?

Research feline leukemia. Make a poster showing where the disease is found geographically, how a cat can be affected, and what can be done to prevent this disease. Make a presentation to your class.

Connect to... Physics

Viruses are so small that they pass through fine procelain filters, but the smallest cells cannot be filtered. *Infer* from this information whether viruses are cells.

Viruses Affect All Organisms

Viruses cause disease in plants, animals, fungi, bacteria, and protists. Tobacco mosaic virus infects tobacco plants and tomato plants. Animal viruses that you might know about are rabies, chicken pox, and mumps. If you have a cat, you might also know about the feline leukemia virus. Some RNA and DNA viruses can change healthy cells into cancerous tumor cells.

Preventing Diseases

There are no medications to *cure* viral diseases. But some viral diseases can be *prevented* by vaccines. A **vaccine** is made from damaged particles that can't cause disease anymore. Vaccines have been developed for measles and polio, and for bacterial diseases as well.

The first vaccine was developed in 1798 by Edward Jenner, an English doctor. Jenner developed a vaccine for smallpox, a disease that was greatly feared, even into the twentieth century. Jenner noticed that people who milked cows and came down with a disease called cowpox didn't get smallpox. He prepared a vaccine from the sores of milkmaids who had cowpox. When injected into healthy people, the cowpox vaccine seemed to protect them from smallpox. Did Jenner know he was fighting a virus? No. At that time, no one understood what caused disease or how the body fought disease.

One of the body's natural systems for fighting viral infections is called interferon. Interferon is a protein produced in vertebrate cells that stops viruses from infecting other cells in that animal. Interferon "interferes" with the production of viruses and may have some antitumor features.

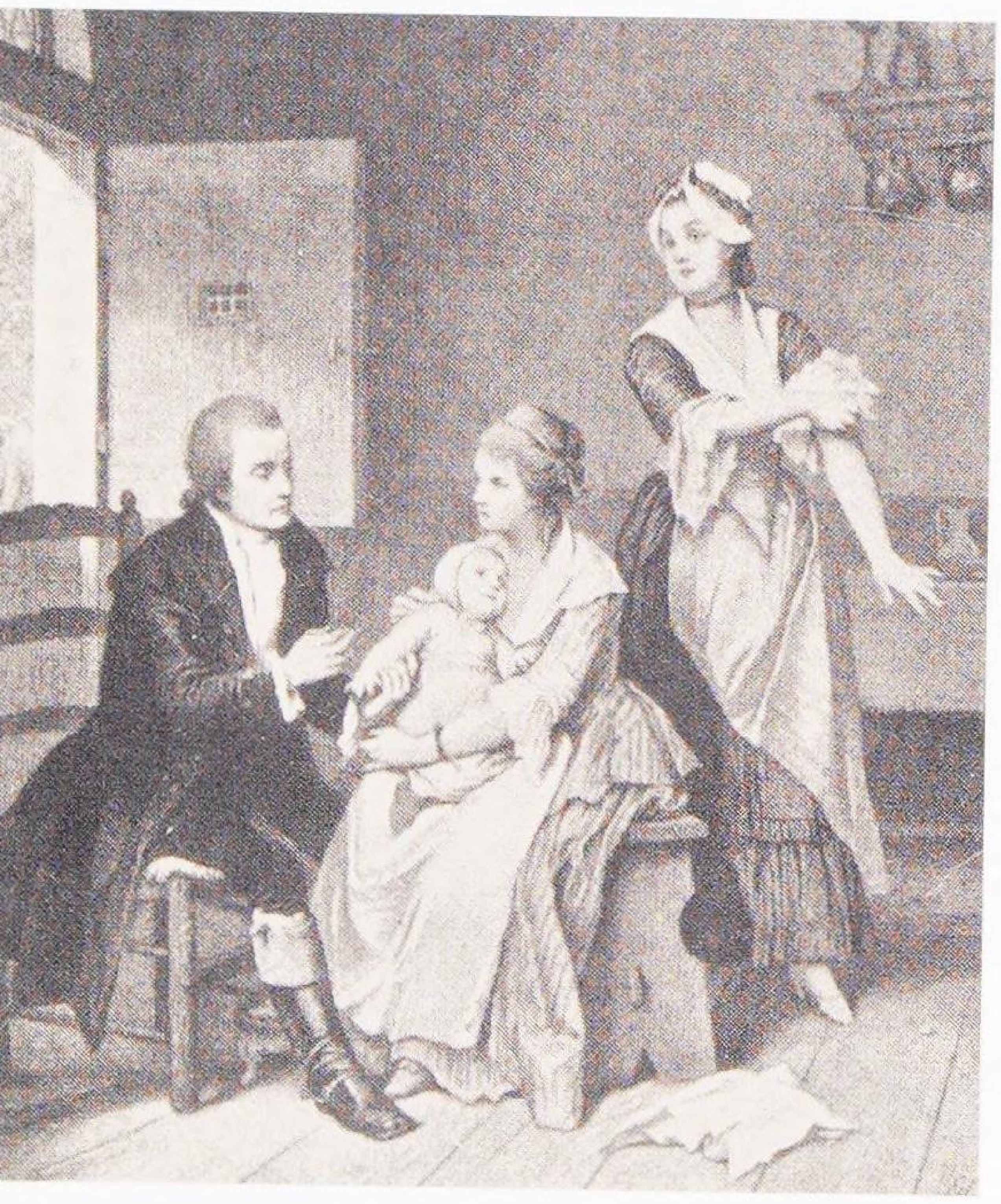


Figure 8-3. Edward Jenner developed the first vaccine in 1798.

Table 8-1

VACCINES AGAINST DISEASE	
Caused by Viruses	**Caused by Bacteria**
Flu	Whooping cough
Measles	Diphtheria
German measles	Tuberculosis
Smallpox	Gangrene
Polio	Tetanus
Rabies	Typhoid fever
Mumps	Cholera

Are There Any Good Viruses?

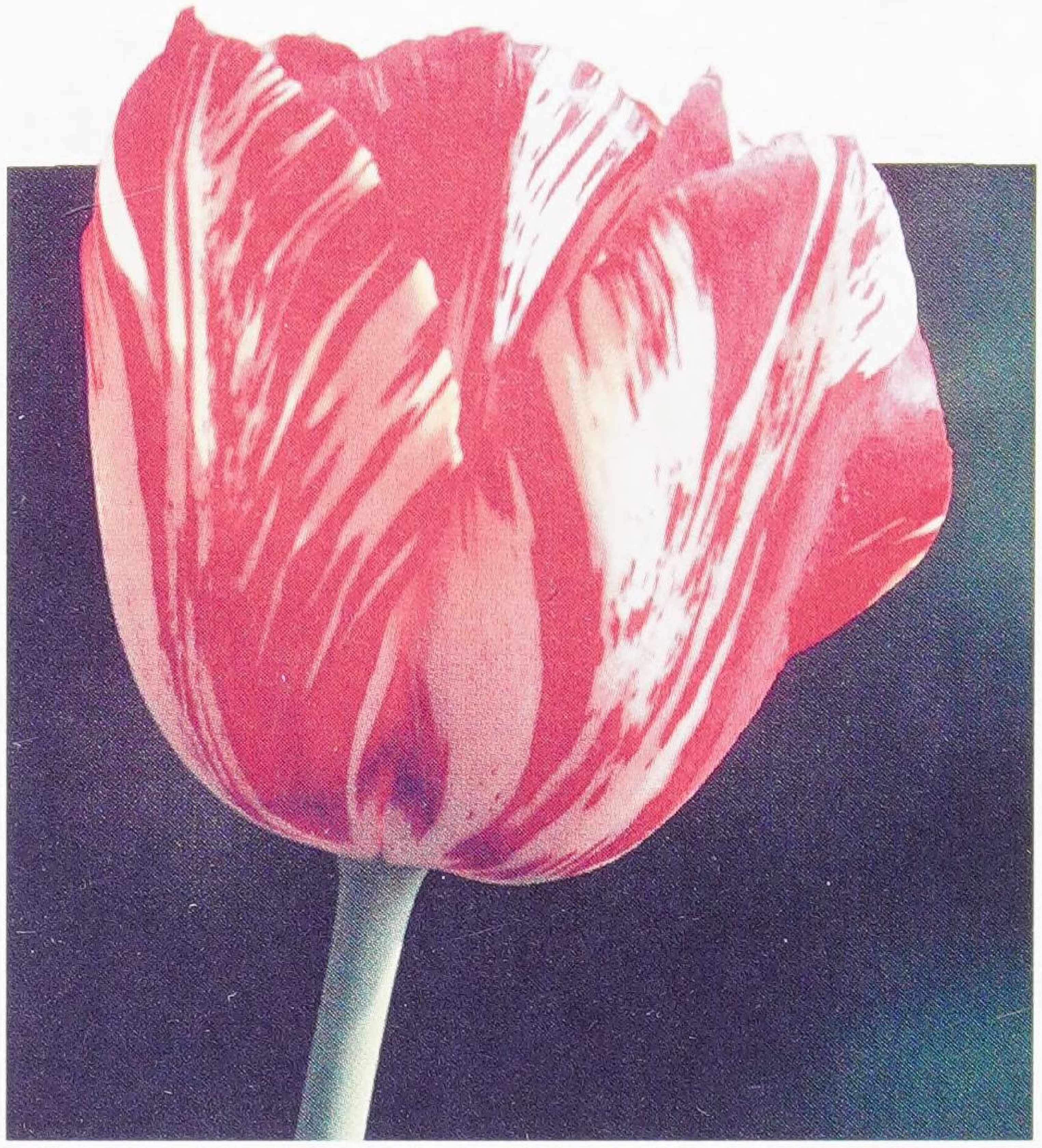


Figure 8-4. The streaked color pattern in this tulip is the result of a viral infection. If the virus stops infecting the tulip, it will develop a more solid color.

Most of what you hear about viruses makes you think that viruses always act in a harmful way. However, there are some cases where, through research, scientists are discovering uses for viruses that may make them helpful.

One method, called gene therapy, involves substituting correctly coded DNA for a cell's incorrect DNA. Correctly coded DNA is enclosed in a virus. The virus then acts like an ambulance, taking the strand of DNA into defective cells to replace the incorrect DNA.

Using gene therapy, scientists hope to help people with genetic disorders. For example, some people have the genetic disorder sickle-cell anemia. Because of a defective gene, hemoglobin in their red blood cells does not release oxygen when it reaches body tissues. With the help of a virus, a repaired gene was allowed to "infect" blood cells in a mouse, and the mouse blood cells began to produce the correct substance. Researchers are hoping to use similar techniques for cancer patients.

SECTION REVIEW

1. Describe the structure of viruses and explain how viruses reproduce.
2. Explain how vaccines work.
3. Explain how viruses may be helpful in the process of gene therapy.
4. **Apply:** Explain why the doctor wouldn't give you a vaccine if you had a cold caused by a virus.
5. **Connect to Chemistry:** Find out what kind of nucleic acids (RNA or DNA) is in HIV and the virus that causes chicken pox.

Hypothesizing

Skill Builder

You are a researcher in a laboratory. The bacterial cells in an experiment you have been working on have reproduced in large numbers. Then, all of a sudden, most of the bacteria begin to die. You need to find out what caused the deaths of the bacteria. What hypothesis can you make about what is happening to the bacteria? If you need help, refer to Hypothesizing in the **Skill Handbook** on page 686.

SCIENCE & SOCIETY

8-2 The Cost of Curing a Disease

New Science Words

AIDS

Objectives

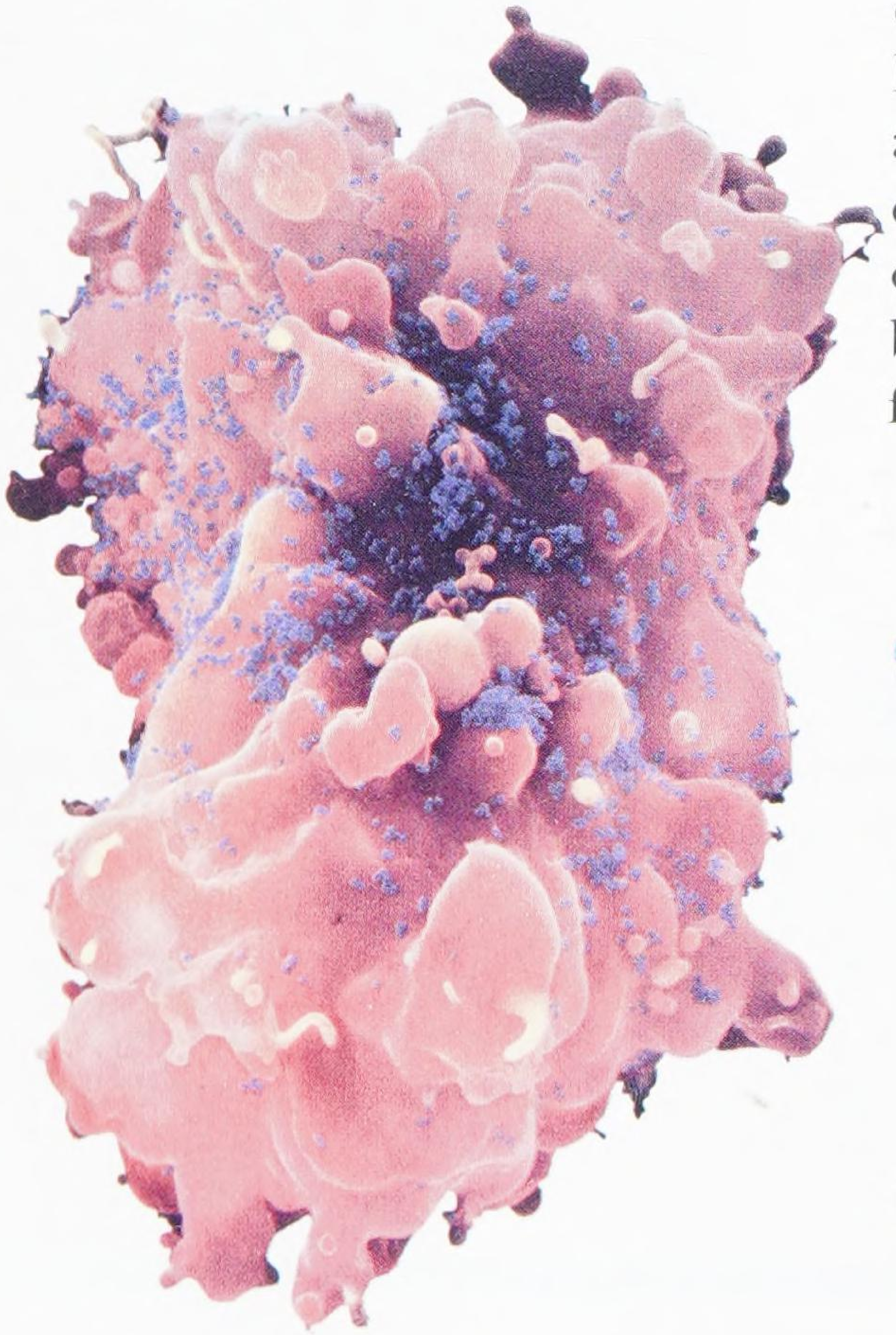
- Define AIDS and explain how it attacks the body.
- Estimate the cost of curing AIDS.

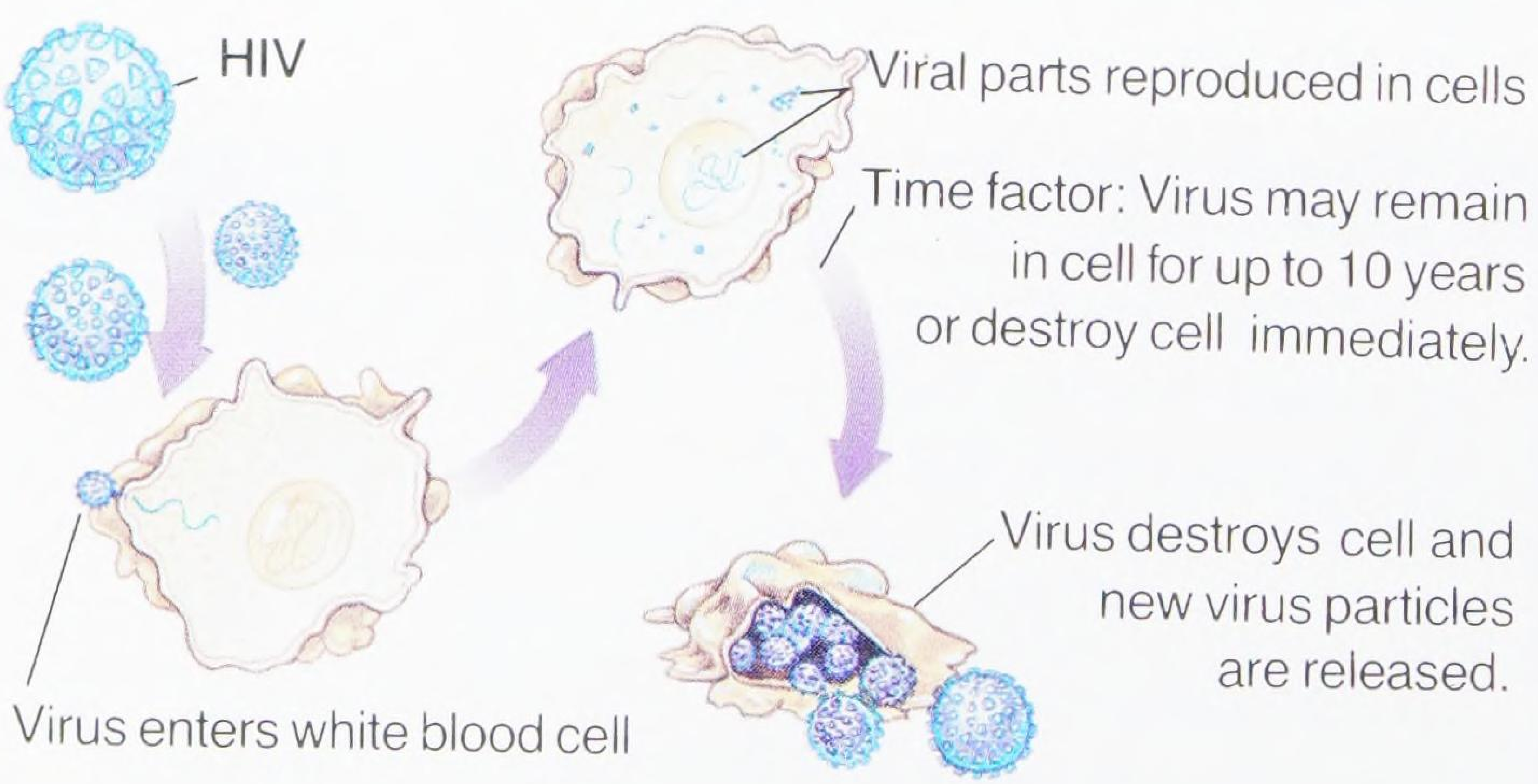
AIDS

AIDS, acquired immune deficiency syndrome, is a group of diseases caused by an RNA virus called HIV. Within a decade of its discovery, AIDS became an epidemic, causing more than 300 000 deaths throughout the world. In 1992, more than one million people in the United States were thought to be infected with HIV. Of these, more than 20 percent have developed AIDS.

From an intensive study of HIV, scientists know that the virus is spread in body fluids. Most people get HIV through sexual contact. You can't get the virus through casual contacts such as hugging, kissing, or shaking hands. Many drug users get HIV by using contaminated syringes and needles. A pregnant or nursing female with AIDS can pass HIV to her baby. Before a test for HIV was developed, some became infected through contaminated blood transfusions. Now the risk of infection from transfusion is low.

Figure 8-5. In this scanning electron micrograph, HIV particles (colored blue) attack a large white blood cell.




HIV
Viral parts reproduced in cells
Time factor: Virus may remain in cell for up to 10 years or destroy cell immediately.
Virus destroys cell and new virus particles are released.
Virus enters white blood cell

HIV attacks certain white blood cells that normally protect the body from infection and disables the body's immune system. A person with HIV becomes unable to protect him- or herself from other types of viruses or bacteria that cause infections. People with HIV often develop pneumonia, tuberculosis, and certain forms of cancer. These diseases are called indicator illnesses. People with HIV die from these indicator illnesses rather than from HIV itself.

Scientists and medical doctors are working to combat AIDS by studying the virus and by using new drug therapies. No vaccine has yet been developed. Only a few drugs, AZT, ddI, and ddC have been approved for treatment. These drugs do not cure but only treat symptoms and, in some cases, prolong life. In order to make helpful drugs available as soon as possible, the Food and Drug Administration (FDA) has made exceptions to its own rules by approving drugs early for use in the fight against AIDS. AZT won approval for use in less than four months. Normally it takes an average of two years for a new drug to be approved for use.

AIDS is different in other respects. People disagree on the seriousness of the threat of HIV infection. They also disagree on how much money should be spent on finding a cure for AIDS and on educating people about HIV infection. Each year the government spends billions of dollars on research for diseases that are major causes of death in the United States. At the present time, more money is spent on AIDS research than on either cancer or heart disease, both of which cause more deaths than AIDS.

Figure 8-6. AZT is a drug used to combat AIDS infection.

In Your JOURNAL

Write a one-page paper **in your Journal** explaining why it is important to know the facts about AIDS.

SECTION REVIEW

1. What is AIDS and how is it spread?
2. How does HIV affect the immune system?
3. Why are people with AIDS more likely to die from indicator illnesses?
4. **Connect to Chemistry:** Find out how AZT, ddI, or ddC work in the body.

You Decide!

SCIENCE & SOCIETY

The cost of medical research and treatment is presently a topic of great concern to taxpayers. If you were in control of the federal budget, how would you determine how to spend money on research and treatment of AIDS and other diseases?

8-3 Kingdom Monera

New Science Words

flagellum
fission
aerobes
anaerobes

Objectives

- Describe the characteristics of moneran cells.
- Compare aerobic and anaerobic organisms.

What Is a Moneran?

In Chapter 2, you read about two types of cells—prokaryotic cells and eukaryotic cells. Prokaryotes are organisms whose cells have no membrane-bound organelles. Monerans are simple-looking, one-celled organisms. They are prokaryotes. Their nuclear material consists of a single circular chromosome. Monerans don't have organelles such as mitochondria or chloroplasts but they do contain ribosomes.

How do monerans obtain energy?

Monerans have a few plantlike characteristics. They have cell walls as plants do. Some monerans contain chlorophyll. This enables them to use carbon dioxide and sunlight to make their own food.

Most monerans, however, don't make their own food. That means they have to rely on other organisms to provide food. These monerans have to break down, or decompose, other living things to obtain energy. If you've ever helped clean out the refrigerator, you've probably run into some things that smelled bad. A moneran was at work decomposing a forgotten leftover. In nature, monerans and fungi keep the world free of wastes by breaking them down. In doing so, they also release nutrients into the soil for use again. There are two groups of monerans. One you know as bacteria. The other is cyanobacteria.

Figure 8-7. Bacteria are decomposers. They break down living tissues.

Bacteria

When most people hear the word *bacteria,* they probably associate it with sore throats or gum disease. However, very few bacteria cause illness. Most are important for other reasons. Bacteria are almost everywhere—in the air you breathe, the food you eat, and the water you drink. A shovelful of soil contains billions of them. Hundreds of thousands of bacteria live on and in your body. Most are beneficial to you.

The bacteria that normally inhabit your home and body have three basic shapes—spheres, rods, and spirals. Sphere-shaped bacteria are called *cocci,* rod-shaped bacteria are called *bacilli,* and spiral-shaped bacteria are called *spirilla.* The general characteristics of bacteria can be seen in the bacillus shown in Figure 8-9b. It contains cytoplasm, surrounded by a cell membrane and wall. The nuclear material is in the form of a single chromosome strand. Some bacteria have a thick gel-like capsule around the cell wall. The capsule helps the bacterium stick to surfaces. How would a capsule help a bacterium to survive?

Many bacteria float freely in the environment on air and water currents, your hands, your shoes, and the family dog or cat. Many that live in very moist conditions have a whiplike tail called a **flagellum** to help them move.

Most bacteria reproduce by fission, as shown in Figure 8-9a. **Fission** produces two cells with genetic material exactly like the parent cell's. Some bacteria also reproduce by a simple form of sexual reproduction. Two bacteria line up beside each other and exchange some DNA through a fine tube. This produces cells with different genetic material that may have an advantage in surviving in their environment.

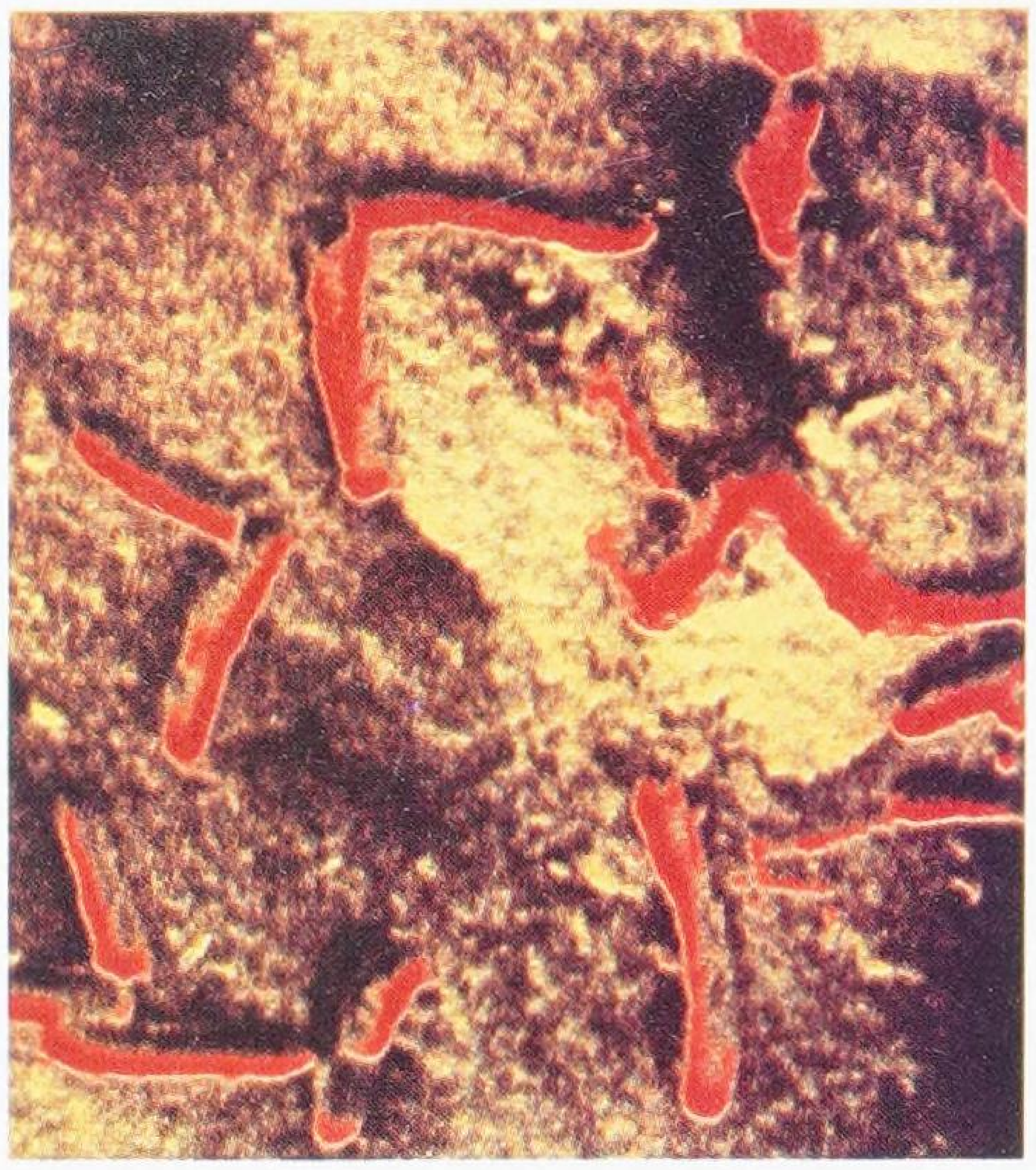
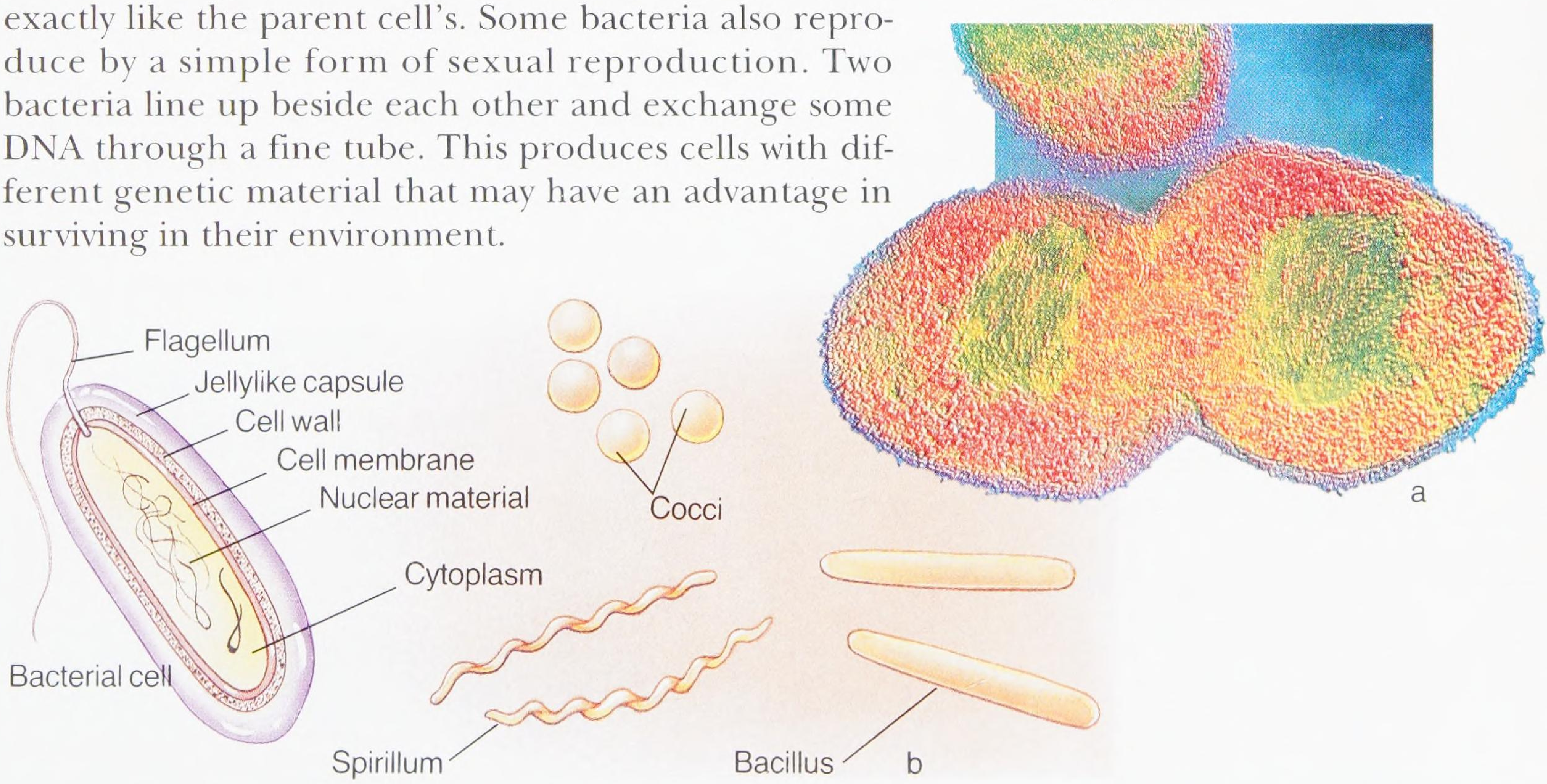


Figure 8-8. Bacteria that grow in plaque in your mouth produce acids that break down tooth enamel.

Figure 8-9. In the photograph, a bacterium is undergoing fission (a). The characteristics and common shapes of bacteria are also shown (b).



Connect to...

Physics

One characteristic used to classify bacteria is the "wavelengths" of their flagella. In physics, each color in the visible spectrum has a wavelength. Find out the sequence of colors of light in the visible spectrum from the shortest to the longest wavelength.

Most bacteria live in places where there is a supply of oxygen. Organisms that use oxygen for respiration are called **aerobes.** You are an aerobic organism. In contrast, some organisms, called **anaerobes,** can live without oxygen. For a few types of bacteria, oxygen is even deadly.

Certain species of anaerobic bacteria are thought to have existed for millions of years. They are found in extreme conditions, such as hot springs, salty lakes, muddy swamps, the intestines of cattle, and near vents deep in the ocean where sunlight doesn't penetrate.

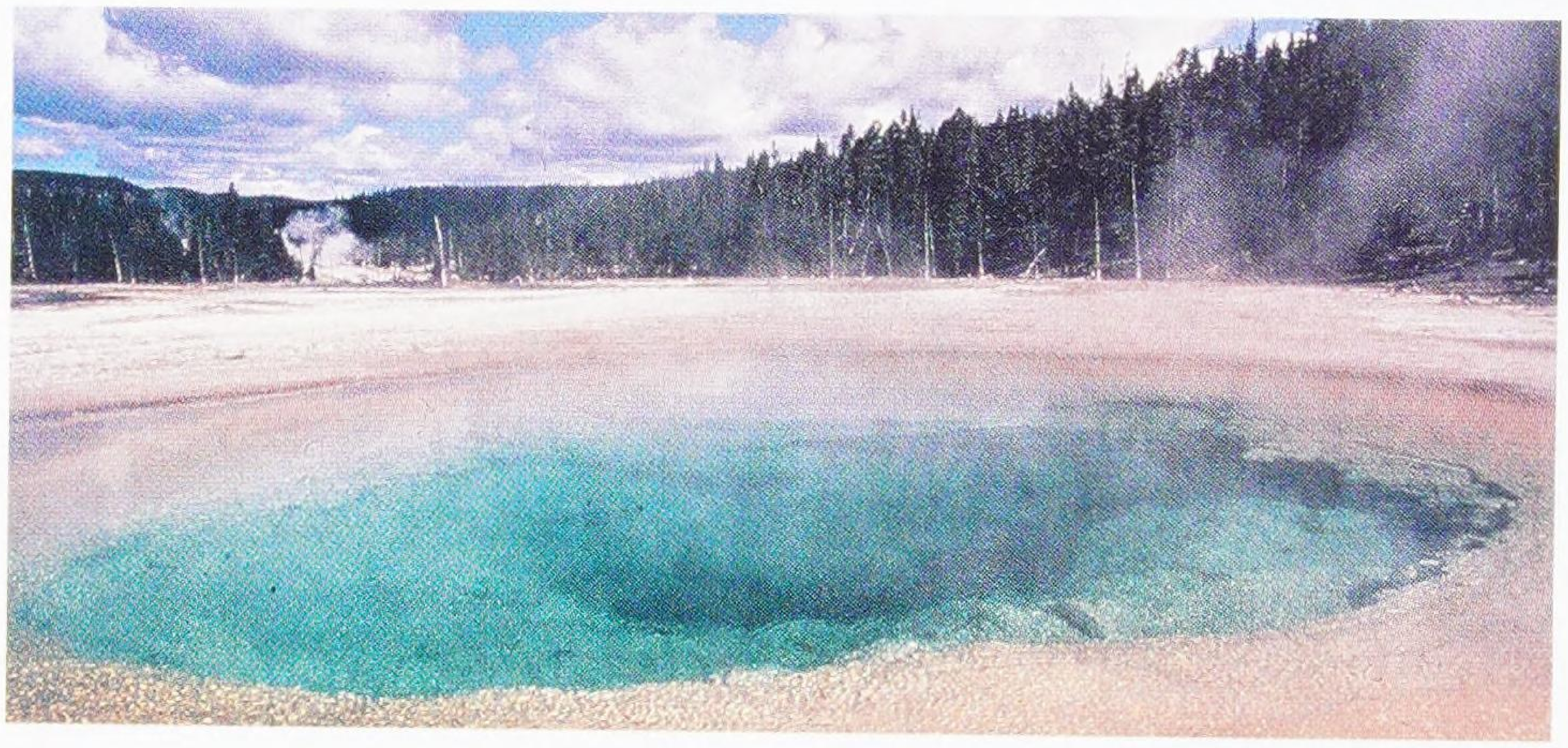


Figure 8-10. Bacteria that can survive in hot springs are similar to ancient forms.

PROBLEM SOLVING

How Are *E. coli* Bacteria Helpful?

Sarah's class was studying bacteria in life science. The teacher mentioned a common bacterium called *Escherichia coli,* which is found in the intestines of humans and other animals. The teacher explained that these bacteria help break down foods that otherwise would not be digested and produce materials such as vitamins.

While watching the news on TV, Sarah learned that people in a flooded area of her state were being told to boil their water. A test had shown high levels of *E. coli* bacteria in the water. She wondered why the water had been tested for *E. coli* and not for other disease-causing bacteria.

Think Critically: Why were the people in the flood area told to boil their water? Why are *E. coli* bacteria used as an indicator that water is harmful to drink?

Cyanobacteria

Cyanobacteria are monerans that are producers. They make their own food using carbon dioxide and sunlight. Cyanobacteria contain chlorophyll and another pigment that is blue. The pigment combination gives cyanobacteria their common name, blue-green bacteria. But, in fact, not all cyanobacteria are blue-green. Some are yellow or black or red. The Red Sea gets its name from red cyanobacterium.

All species of cyanobacteria are one-celled organisms. However, some of these organisms live together in long chains or filaments. Many are covered with a gel-like substance. This allows them to live in globular groups called colonies. Individual cells reproduce by fission. They do not contain mitochondria, chloroplasts, or nuclei. Cyanobacteria are important for food production in lakes and ponds. Because cyanobacteria make food from sunlight, fish in a healthy pond can eat them and utilize the energy released from that food.

Have you ever seen a pond covered with smelly, green, bubbly slime? When large amounts of nutrients enter a pond, cyanobacteria increase in number and produce a matlike growth called a bloom. The cyanobacteria die. Bacteria feed on them and use up all the oxygen in the water. As a result, fish and other organisms die.

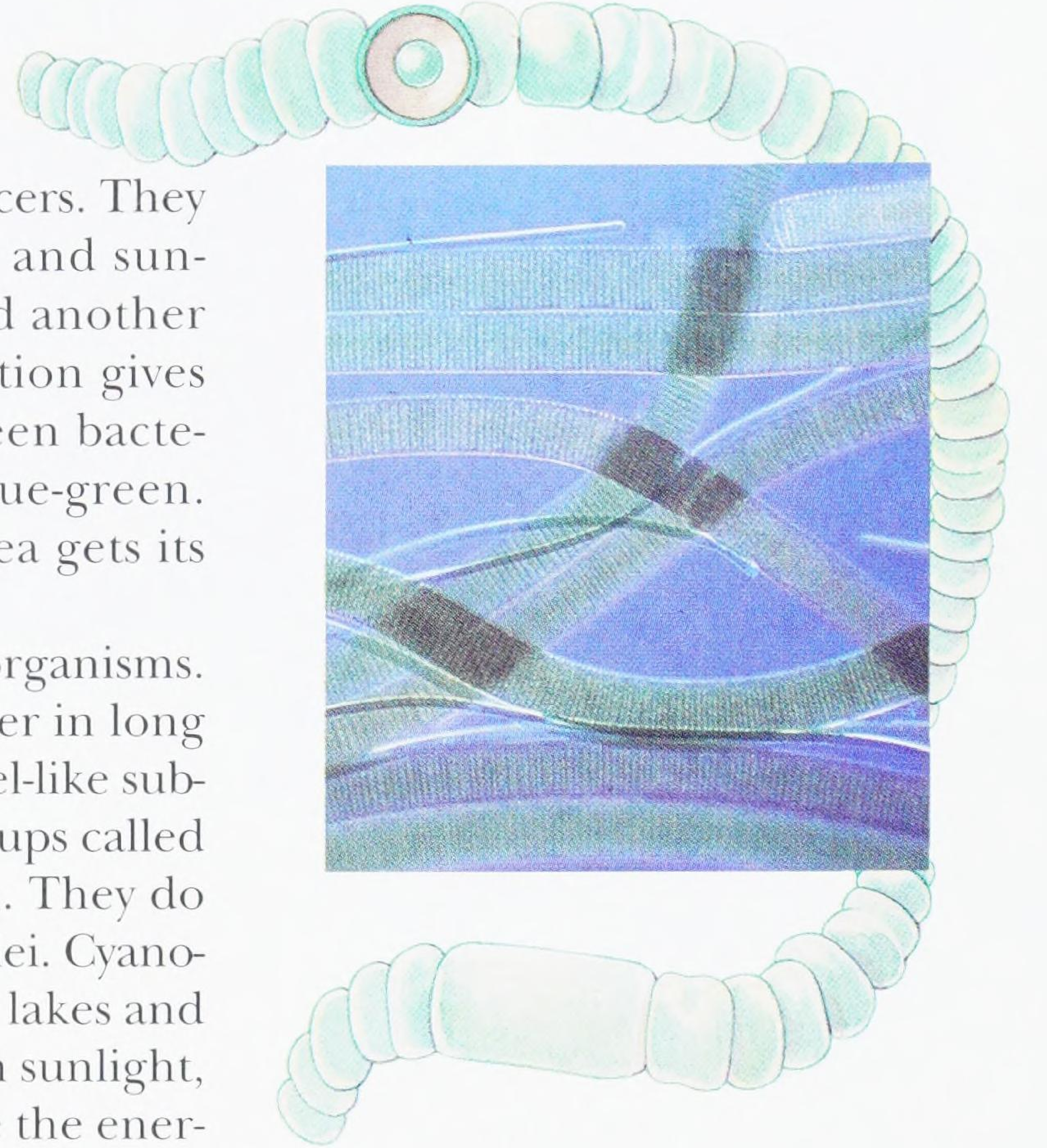


Figure 8-11. Some species of cyanobacteria exist as filaments. The photograph shows *Oscillatoria,* which grows on damp soil and can make stones slick in damp areas. The drawing is of a colony of *Anabaena*, commonly found in ponds.

SECTION REVIEW

1. What are the characteristics of monerans?
2. How can you infer that cyanobacteria undergo photosynthesis?
3. How do aerobic and anaerobic organisms differ?
4. **Apply:** A mat of cyanobacteria is found growing on a lake with dead fish floating along the edge. What has caused this to occur?
5. **Connect to Chemistry:** Find out how bacteria attack tooth enamel.

Concept Mapping

Skill Builder

Use an events chain concept map to show what happens in a pond when a bloom of cyanobacteria dies. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

ACTIVITY 8-1

Observing Cyanobacteria

Problem: *What do cyanobacteria look like?*

Materials

- microscope
- prepared slides of *Gloeocapsa* and *Anabaena*
- living cultures of *Nostoc* and *Oscillatoria*

Procedure

1. Make a data table like the one shown. In it, you will indicate whether each cyanobacteria sample is in colony form or filament form. Write a yes or no for the presence or absence of each characteristic in each type of cyanobacteria observed.
2. *Observe* the prepared slides of *Gloeocapsa* and *Anabaena* under the low and high power of the microscope. Notice the difference in the arrangement of the cells. The large cells in the *Anabaena* filaments fix nitrogen. The jelly-like capsules around *Gloeocapsa* cells help them to stick together in a group. Draw and label a few cells of each cyanobacterium.
3. Make a wet mount of each living culture. Observe under low and high power of the microscope. Watch for larger nitrogen-fixing cells in *Nostoc*. **In your Journal,** draw and label a few cells of each cyanobacterium.
4. *Return all slides with living material to your teacher for disposal.*
5. Wash your hands before continuing.

Analyze

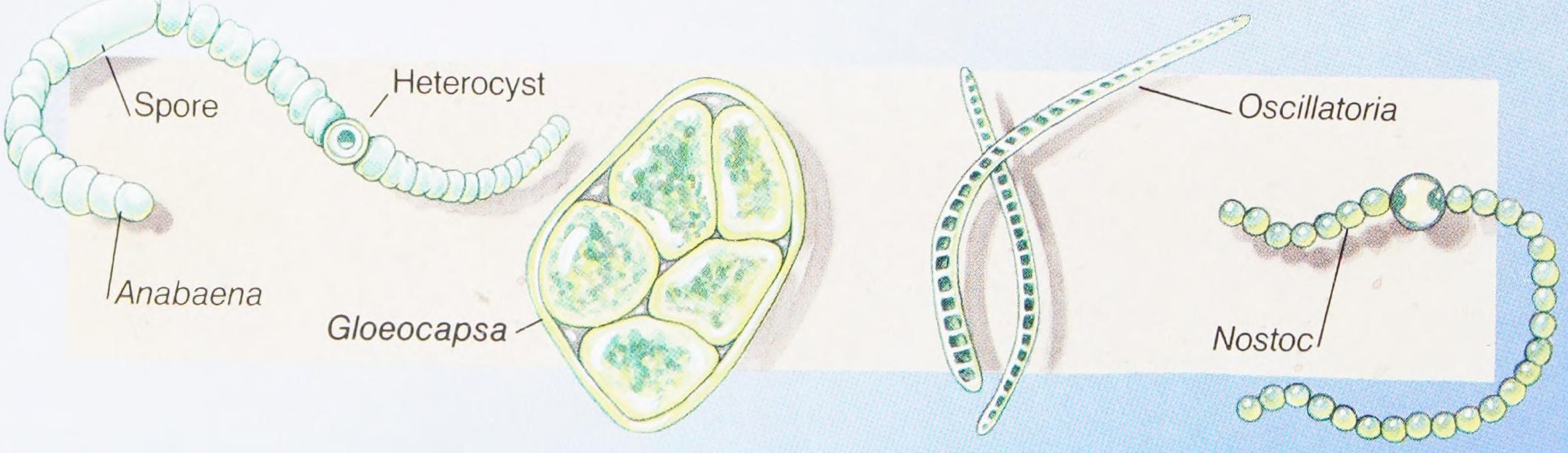
1. How does the color of cyanobacteria compare with the color of leaves on trees? What can you *infer* from this?
2. What is the purpose of the jelly-like layers around some cyanobacteria?

Conclude and Apply

3. How can you tell by observing them through a microscope that cyanobacteria belong to Kingdom Monera?
4. Describe the activities and general appearance of live cyanobacteria.

Data and Observations

Structure	Anabaena	Gloeocapsa	Nostoc	Oscillatoria
Filament or colony				
Nucleus				
Chlorophyll				
Jelly-like layer				
Nitrogen-fixing cells				



Monerans in Your Life

8-4

Objectives

- Identify some ways bacteria are helpful.
- Explain the importance of nitrogen-fixing bacteria.
- Explain how some monerans cause disease.

New Science Words

saprophyte
nitrogen-fixing bacteria
pathogen
antibiotic
toxins
endospores

Helpful Monerans

Have you had any monerans for lunch lately? Anytime you eat cheese or yogurt, you eat some bacteria. Bacteria break down substances in milk to make these everyday products. If you have eaten sauerkraut, you ate a product made with cabbage and a bacterial culture. Vinegar is also made by a bacterium.

Many industries rely on bacteria. Biotechnology has put bacteria to use in making medicines, enzymes, cleansers, adhesives, and other products. Bacteria have been extremely important in helping to clean up the extensive oil spills in Alaska, California, and Texas.

Monerans called saprophytes (SAP ruh fitz) help maintain nature's balance. A **saprophyte** is any organism that uses dead material as a food and energy source. Saprophytes digest dead organisms and recycle nutrients so that they are available for use by other organisms. Without saprophytic monerans, there would be layers of dead material deeper than you are tall spread over all of Earth.

MINI-Lab

How do you make yogurt?
Bring a quart of milk almost to a boil in a saucepan. **CAUTION:** *Always be careful when using a stove or hot plate.* Remove the pan from the burner. Cool the milk to lukewarm. Add one or two heaping tablespoons of yogurt starter and stir. Pour the mixture into a clean thermos bottle and put on the lid. Let stand for six hours and then refrigerate. *Infer* why you let the milk cool before adding the starter.

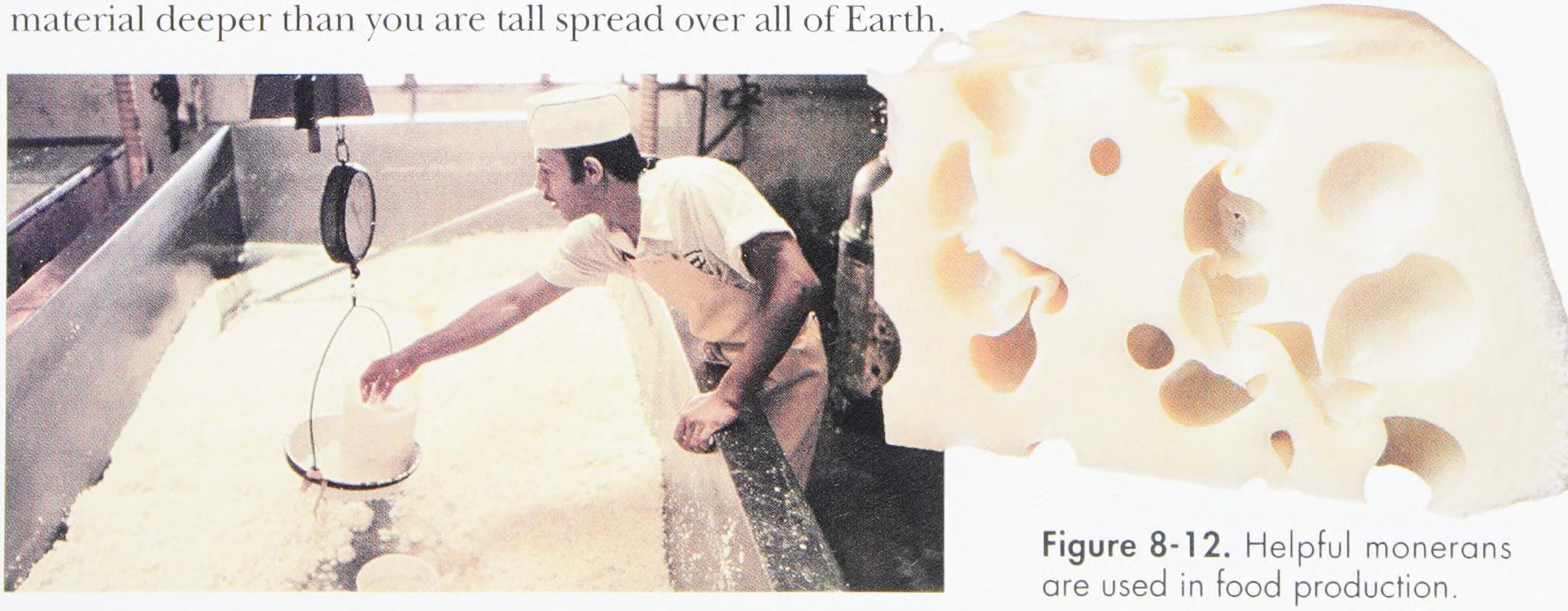


Figure 8-12. Helpful monerans are used in food production.

The roots of plants such as peanuts and peas contain **nitrogen-fixing bacteria** in growths called nodules. These bacteria change nitrogen from the air into forms useful for plants and animals. Plants benefit by using the nitrogen, and animals benefit because they obtain nitrogen for making needed proteins. It is estimated that nitrogen-fixing bacteria save United States farmers several million dollars in fertilizer costs every year.

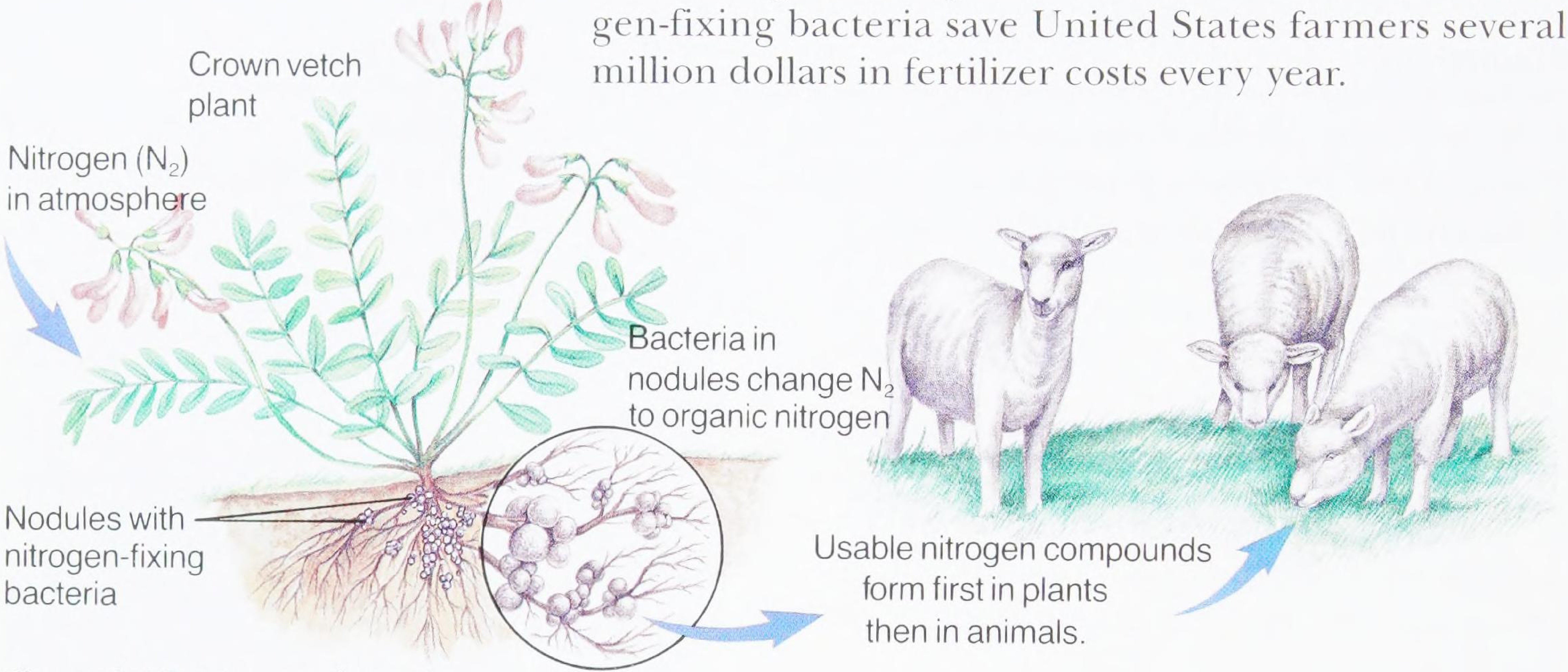

Crown vetch plant
Nitrogen (N_2) in atmosphere
Bacteria in nodules change N_2 to organic nitrogen
Nodules with nitrogen-fixing bacteria
Usable nitrogen compounds form first in plants then in animals.

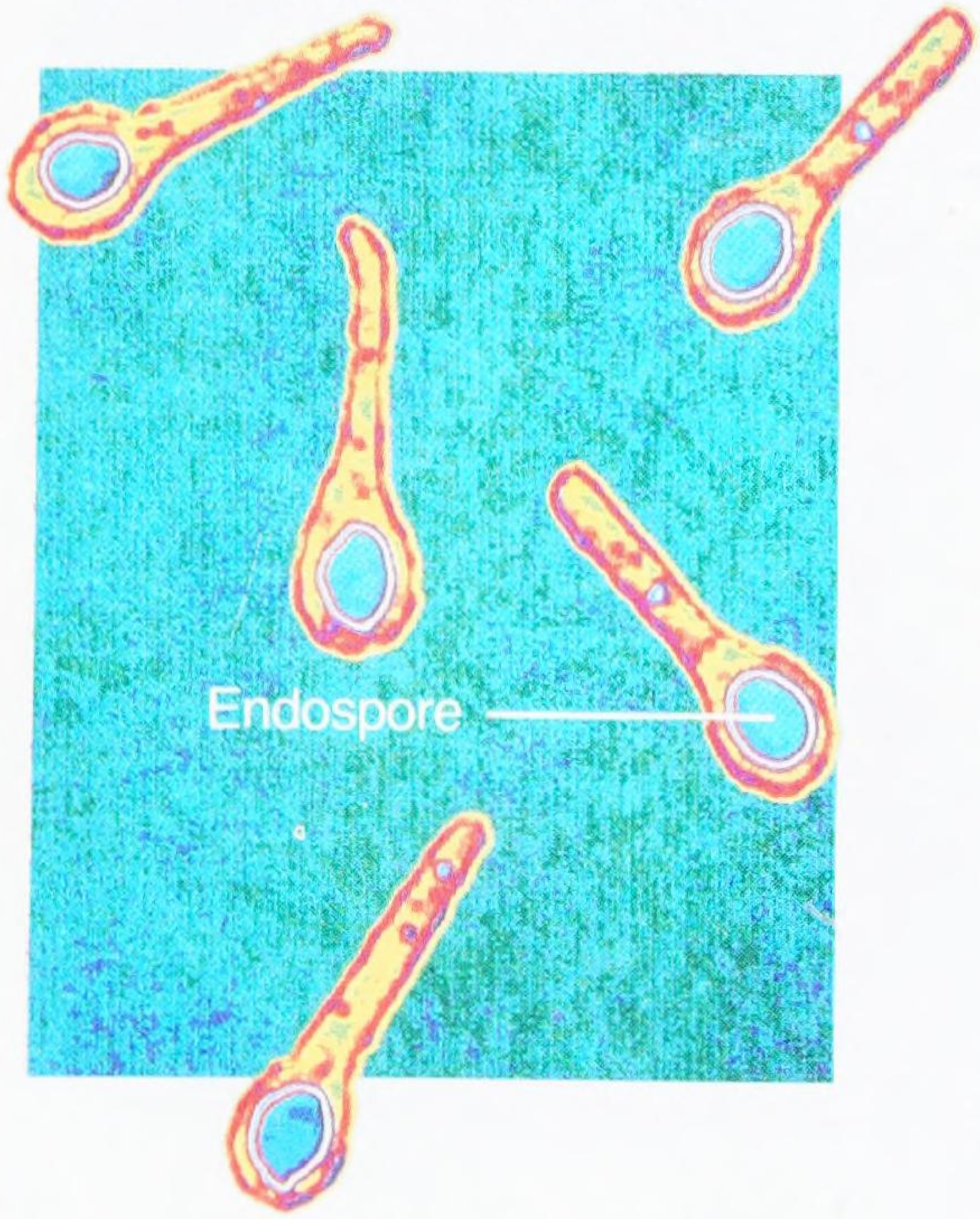
Figure 8-13. Nitrogen-fixing bacteria live in nodules on roots.

Harmful Monerans

Some monerans are pathogens. A **pathogen** is any organism that produces disease. If you have ever had strep throat, you have had firsthand experience with a bacterial pathogen. Other pathogenic bacteria are anthrax in cattle, and diphtheria, tetanus, and whooping cough in humans. Bacterial diseases in animals are treated effectively with antibiotics. An **antibiotic** is a substance produced by one organism that inhibits or kills another organism. Penicillin, a well-known antibiotic, works because it prevents bacteria from making cell walls.

Some pathogens produce poisons called **toxins.** Botulism, a type of food poisoning, is caused by a toxin that can cause paralysis and death. Many bacteria that produce toxins are able to produce thick walls around themselves and make themselves resistant to heat or drying. These thick-walled structures are called **endospores.** Botulism endospores require long exposure to heat to be destroyed. Once the endospores are in canned food, the bacteria can change back to regular cells and start producing toxins. Botulism bacteria are able to grow inside cans because they are anaerobes and cannot use oxygen to live. Botulism toxins can be destroyed by heat.

Figure 8-14. Bacterial endospores are heat-resistant structures.



TECHNOLOGY

Hungry Bacteria

Scientists are exploring a new way to remove poisons from soil and water. They are using bacteria to eat away the problem in a technique called *bioremediation.* The name refers to the use of living organisms to break down pollutants.

To clean a toxic site, large populations of resistant bacteria are brought to a problem area. The bacteria reproduce rapidly and eat away the pollutant over several years. When the pollutant is gone, so is the bacteria's food source, and they die off. Bioremediation has been used to clean up oil, gasoline, PCBs, and pesticides.

Think Critically: What are some disadvantages of bioremediation?

Pasteurization, a process of heating food to a temperature that kills harmful bacteria, is used in the food industry. You are most familiar with it in pasteurized milk, but beer and fruit juices are also pasteurized. The term comes from Louis Pasteur, who first formulated the process for the wine industry in the 19th century in France.

Connect to... Physics

Many foods are "vacuum packed." What does this mean? Find out how a vacuum helps prevent food spoilage.

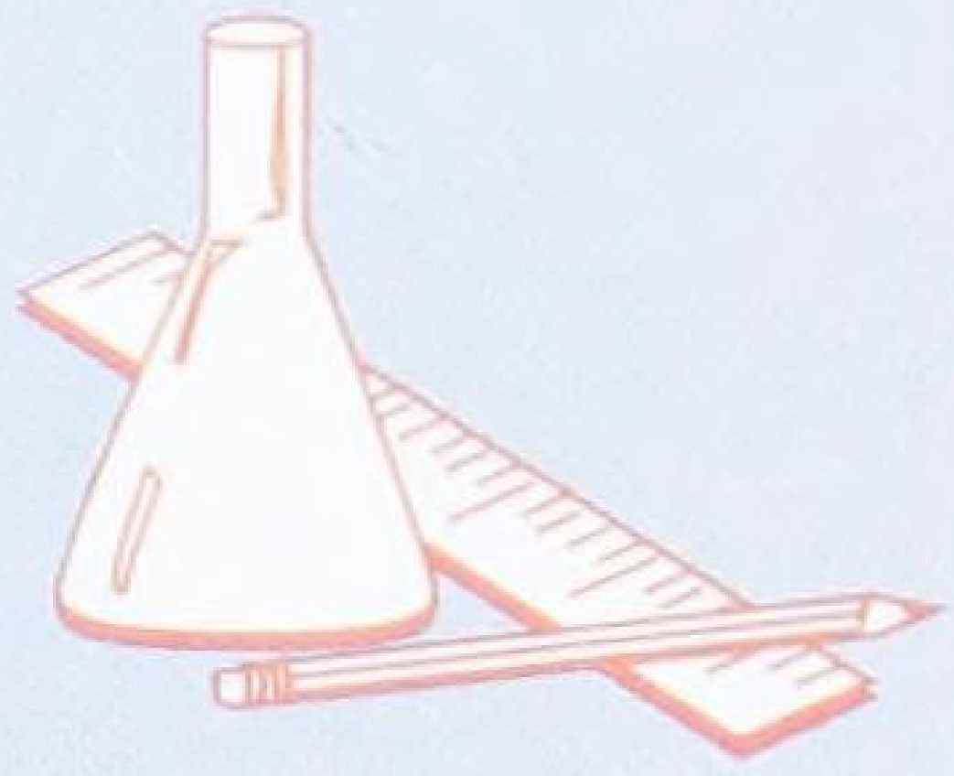
SECTION REVIEW

1. Why are saprophytes helpful and necessary?
2. What is a pathogen?
3. Why are nitrogen-fixing bacteria important?
4. **Apply:** Why is botulism associated with canned foods and not fresh foods?
5. **Connect to Chemistry:** Find out why you have to take penicillin for ten days.

Skill Builder

Measuring in SI

Air may have more than 3500 bacteria per cubic meter. How many bacteria might be in your classroom? If you need help, refer to Measuring in SI in the **Skill Handbook** on pages 684 and 685.



ACTIVITY 8-2

Observing and Culturing Bacteria

Problem: *How can bacteria be observed and cultured?*

Materials

- 600-mL beaker
- microscope
- cotton swabs
- petri dishes (4)
- prepared slide with different types of bacteria
- fork or tongs
- potato
- hot plate
- hot mitts
- knife
- soap and water

Procedure

1. Make a data table like the one shown. Label petri dishes 1, 2, 3, and 4.
2. Peel a potato. Cut it into slices 1 cm thick and put four or five slices in a beaker.
3. Place a fork in the beaker with the potato slices, add water to cover the potato slices, and boil for five minutes.
4. At the end of five minutes of boiling, use the kitchen mitts to transfer one piece of potato to each petri dish. **CAUTION:** *All materials will be hot! Use kitchen mitts to hold the beaker and fork while transferring the potato slices to petri dishes.* Cover each dish and let the slices cool down.
5. Use one swab to innoculate one potato slice with dust. Cover the dish and seal. Touch the inside of your cheek with another swab, then rub the swab on the second slice. Cover and seal the dish immediately. Rub your finger on the third slice once it has cooled. Leave the fourth potato slice in its dish. Seal all dishes and put them in a dark cabinet for three days.
6. Wash your hands with soap and water.
7. **Hypothesize** which dish will have the most bacterial growth.
8. At the end of three days, *observe* the potato slices and record your data. **CAUTION:** *Do not open the dishes. Give all materials to your teacher for disposal.*

Data and Observations

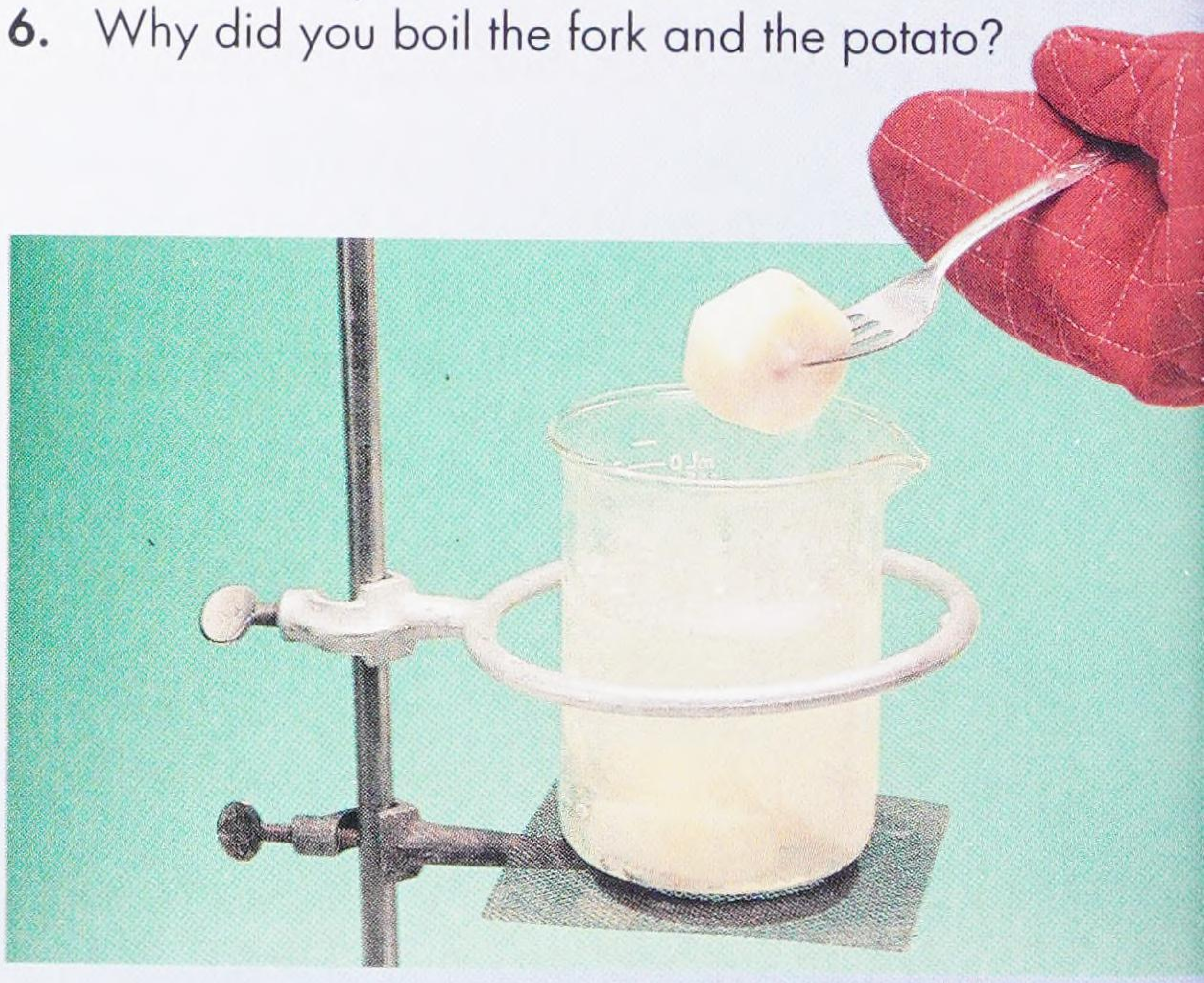
Treatment	Number and appearance of colonies
Dust	
Cheek	
Finger	
Control	

Analyze

1. Which dish had the most colonies? The fewest?
2. What were the constants in the experiment? The variables? Explain the function of dish 4.

Conclude and Apply

3. Was your hypothesis supported or not?
4. How can you tell different species of bacteria by their colonies?
5. *Infer* where you can find bacteria.
6. Why did you boil the fork and the potato?



CHAPTER REVIEW

SUMMARY

8-1: Viruses: Are They Alive?

1. A virus is a structure containing nucleic acid surrounded by a protein coat. A virus can reproduce only inside a living cell. It may destroy a cell immediately or be latent.

2. Vaccines prevent viral infections. Interferon blocks viruses from reproducing.

3. Viruses are used in gene therapy to replace defective DNA with correctly coded DNA.

8-2: Science and Society: The Cost of Curing a Disease

1. AIDS is a deadly human viral disease affecting the immune system.

2. AIDS detroys the body's ability to combat disease, leaving a person with AIDS defenseless. Death results from other infections.

3. The cost of treating AIDS is more than that spent on diseases that affect many more people, such as heart disease, diabetes, and cancer.

8-3: Kingdom Monera

1. Monerans are cells that contain DNA, ribosomes, and cytoplasm; they lack organelles. Most reproduce by fission.

2. Cyanobacteria are monerans that make their own food.

3. The oldest types of monerans are anaerobic, whereas more complex cells need oxygen and are called aerobes.

8-4: Monerans in Your Life

1. Monerans are helpful through recycling nutrients, nitrogen fixation, and use in food production.

2. Some bacteria are harmful because they cause disease. Some diseases are anthrax, tetanus, and botulism.

3. A process like pasteurization keeps food and the environment free of harmful bacteria.

KEY SCIENCE WORDS

a. **aerobes**
b. **AIDS**
c. **anaerobes**
d. **antibiotic**
e. **endospores**
f. **fission**
g. **flagellum**
h. **nitrogen-fixing bacteria**
i. **parasite**
j. **pathogen**
k. **saprophyte**
l. **toxins**
m. **vaccine**
n. **viruses**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. organisms that decompose dead organisms
2. structure by which some organisms move
3. heat-resistant structures in bacteria
4. substance that can prevent, not cure, a disease
5. something that does harm to its host
6. incurable disease caused by an RNA virus
7. organisms that can survive without oxygen
8. harmful chemical produced by some pathogens
9. bacteria in roots that make nitrogen available to organisms
10. microscopic particles that are not alive

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. ______ is an example of a viral disease.
   a. Tuberculosis **c.** Smallpox
   b. Anthrax **d.** Tetanus
2. Moneran cells contain ______.
   a. nuclei **c.** mitochondria
   b. DNA **d.** no chromosomes
3. Monerans that make their own food have ______.
   a. chlorophyll **c.** Golgi bodies
   b. lysosomes **d.** mitochondria
4. Most monerans are ______.
   a. anaerobic **c.** many-celled
   b. pathogens **d.** beneficial
5. Bacteria that are rod shaped are ______.
   a. bacilli **c.** spirilli
   b. cocci **d.** colonies
6. The structure that allows a bacterium to stick to surfaces is the ______.
   a. capsule **c.** chromosome
   b. flagella **d.** cell wall
7. Blooms in ponds are caused by ______.
   a. archaebacteria **c.** cocci
   b. cyanobacteria **d.** viruses
8. Nutrients and carbon dioxide are returned to the environment by ______.
   a. producers **c.** saprophytes
   b. flagella **d.** pathogens
9. ______ is caused by a pathogenic moneran.
   a. nitrogen-fixation **c.** cheese
   b. anti-biotics **d.** strep throat
10. Organisms that may find oxygen deadly are ______.
    a. anaerobes **c.** producers
    b. aerobes **d.** viruses

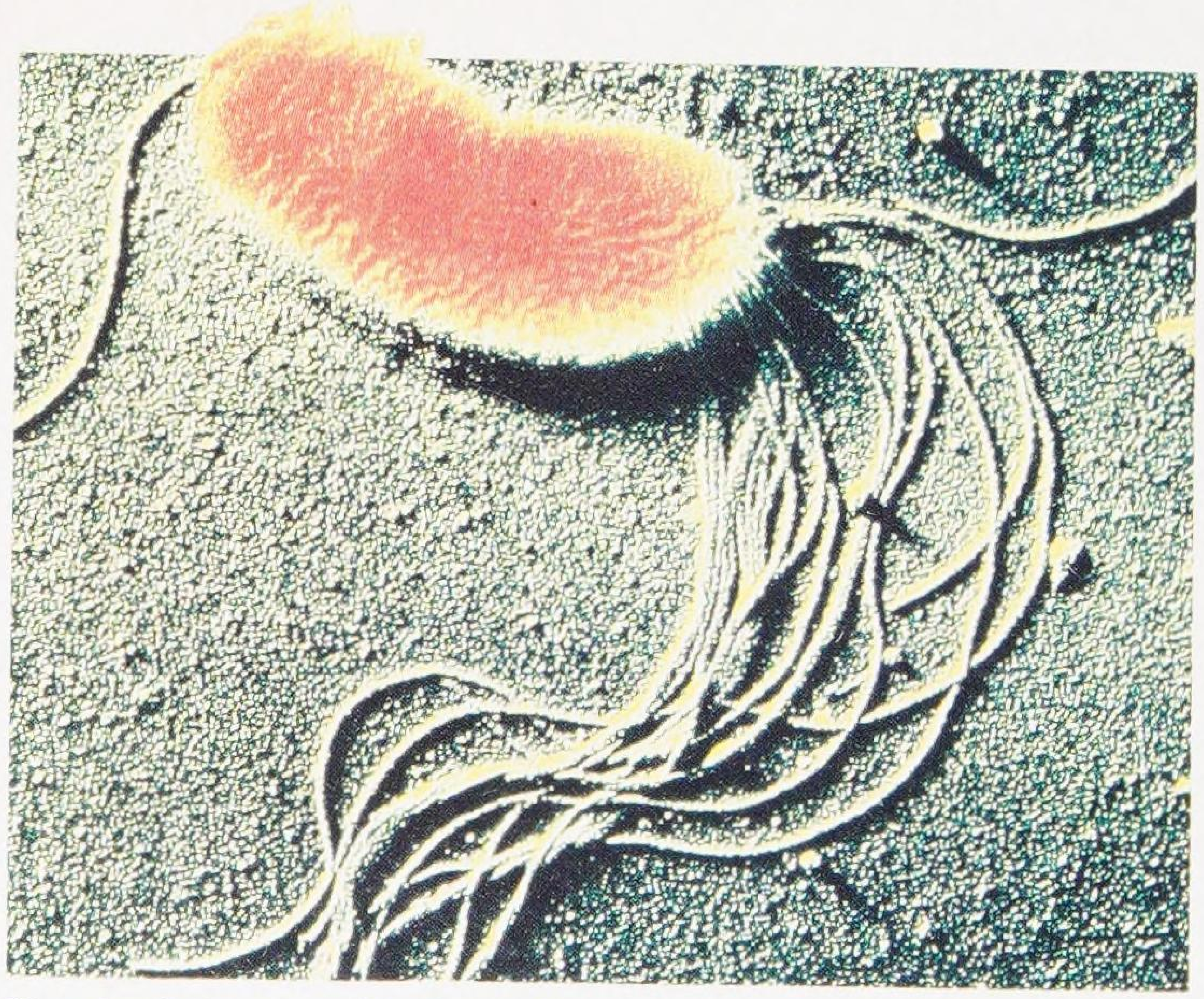
USING LAB SKILLS

11. The Find Out! on page 181 asked you to look at bacteria in yogurt. Assume that there are 50 000 bacteria in every drop of yogurt and there are thirty drops of yogurt in a milliliter. *Calculate* the number of bacteria in a 250 milliliter serving of yogurt.
12. Look at the MINI-Lab on page 193 again. *Design an experiment* that would test the effect of temperature on the final product—homemade yogurt. Carry out your experiment.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal, using complete sentences.

13. Would your classify viruses in a kingdom? Explain your answer.
14. Milk produced by cows is free of bacteria, yet several hours later, it needs to be pasteurized. Why?
15. Why do most AIDS victims die from secondary infections?
16. Explain why monerans are prokaryotes.



Bacterial cell with flagella

APPLY

17. What would happen if nitrogen-fixing bacteria could no longer live on the roots of plants?
18. Why are bacteria capable of surviving in all environments of the world?
19. Why is it difficult to get rid of viruses?
20. The organism that causes bacterial pneumonia is called *Pneumococcus*. What is its shape?
21. What precautions can be taken to prevent food poisoning?

MORE SKILL BUILDERS

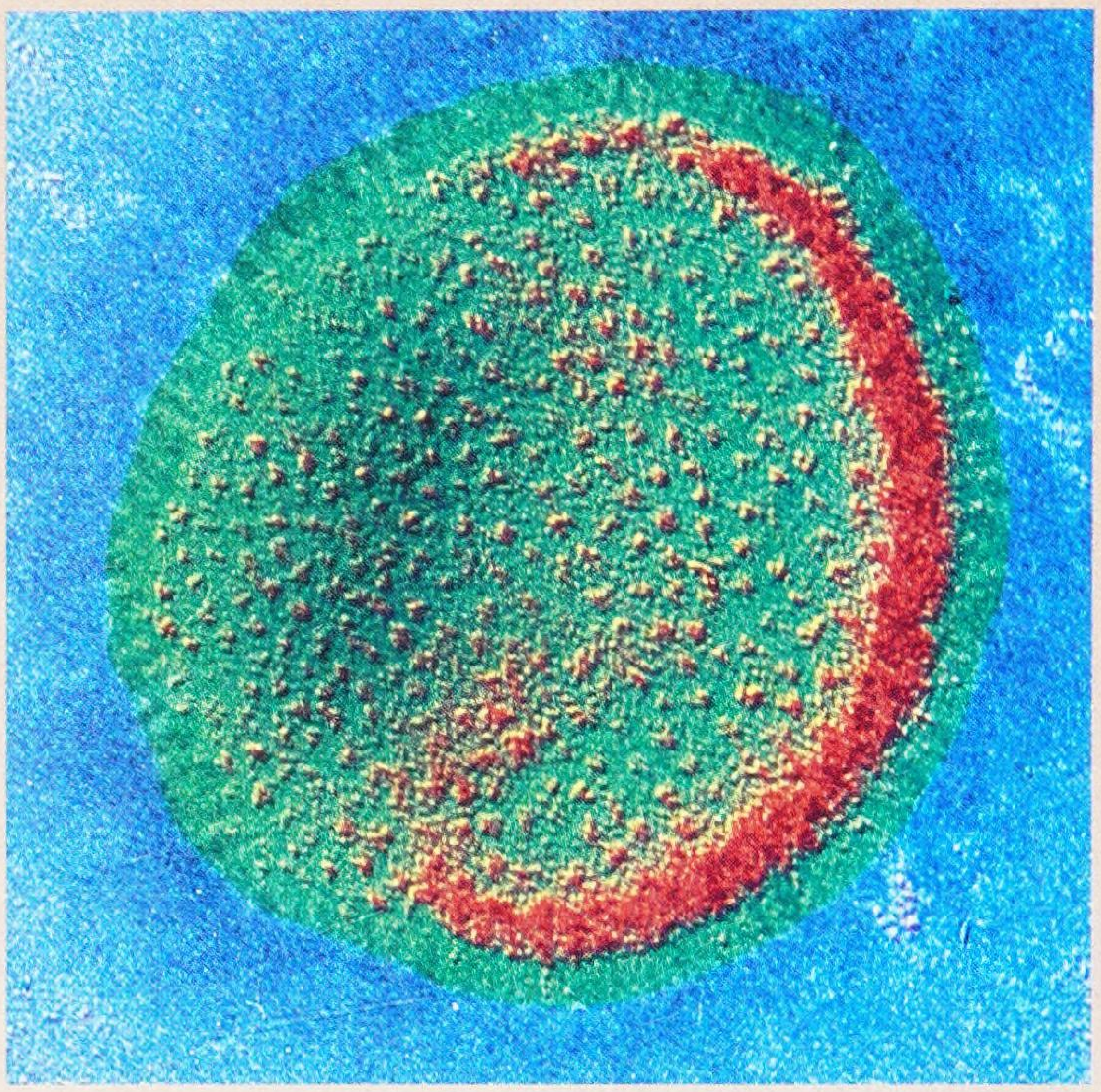
If you need help, refer to the Skill Handbook.

1. **Sequencing:** Sequence the events of a virus actively infecting a cell.
2. **Making and Using Graphs:** Graph the data of viruses reproducing at different temperatures in a human body.

Virus Reproduction

Body Temperature °C	Millions of Viruses
36.9	1.0
37.2	1.0
37.5	0.5
37.8	0.25
38.3	0.10
38.9	0.05

3. **Interpreting Data:** What can you conclude about the effect of rising temperature on the viruses in Question 2?



4. **Concept Mapping:** Make an events chain concept map to show what happens when a latent virus becomes active.
5. **Comparing and Contrasting:** In a table, compare and contrast a virus, a bacterial cell, and a eukaryote cell according to the structures they contain.

PROJECTS

1. **In your Journal,** draw and label a timeline illustrating the history of vaccination. Look up the term *variola* in a library reference and read about early attempts to protect people from disease, especially smallpox.
2. Research the components of a successful compost heap. As a class project, set up a model composting project at your school, indicating the role of bacteria in the process.

CHAPTER

9 Protists and Fungi

Have you ever seen mushrooms growing in your yard or in a field? You may even like to eat mushrooms in salads, casseroles or on pizza. But what do you really know about mushrooms?

FIND OUT!

Do this simple activity to find out more about one of the members of Kingdom Fungi.

Examine a mushroom from the produce section of a grocery store. Carefully pull the cap off the stalk and lay it aside. Use your fingers to pull the stalk apart lengthwise. Continue to pull the stalk apart until the pieces are as small as you can get them. What do you see? Before the mushroom was picked, the stalk was connected to an underground structure by thin strands of tubelike cells. The strands of cells grew up from the ground to form the stalk.

Now look at the underside of the cap. *Observe* the many thin membranes. The brown color comes from the spores along the edges of each membrane. Why are the spores on the membranes?

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 9-1 Kingdom Protista
- What Is a Protist?
- Plantlike Protists
- Animal-like Protists
- Funguslike Protists

Section 9-2 Kingdom Fungi
- What Are Fungi?
- Divisions of Fungi

Section 9-3 Science and Society
Fungus—Can't Live Without It
- Beneficial Fungi

Previewing Science Skills

- In the **Skill Builders,** you will make and use tables and use variables, constants, and controls.
- In the **Activities,** you will observe and compare and contrast.
- In the **MINI-Labs,** you will make observations, predict, experiment, and estimate.

What's next?

Mushrooms are only one type of fungi. In this chapter you will learn more about the organisms in the Kingdom Fungi and their importance to the living world. But first you will learn about the different types of organisms in Kingdom Protista.

9-1 Kingdom Protista

New Science Words

protists
algae
protozoa
pseudopods
cilia

Objectives

- Identify the characteristics shared by all protists.
- Describe the three groups of protists.
- Compare and contrast the protist groups.

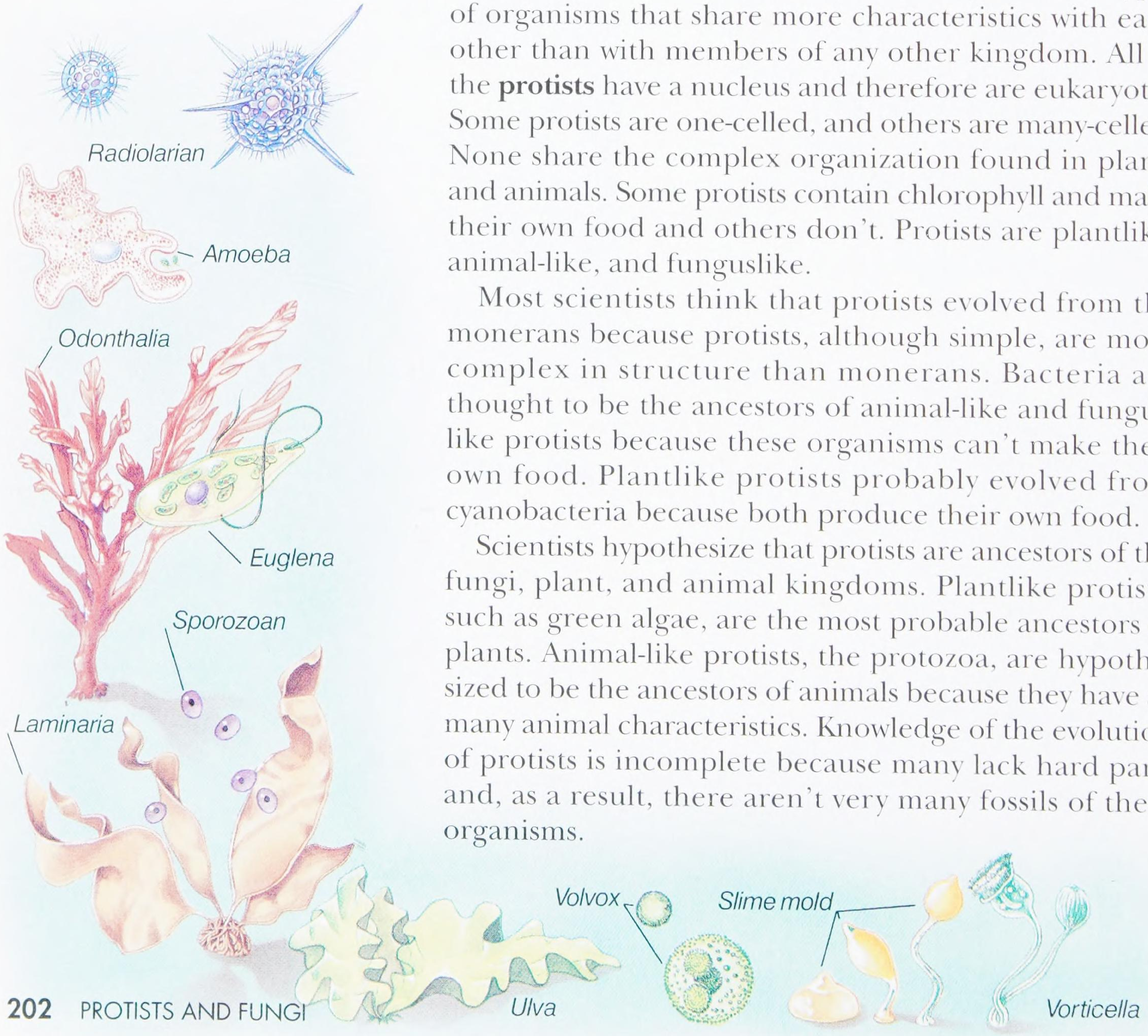
What Is a Protist?

Look at the organisms in Figure 9-1. Do you see any similarities among them? As different as they appear, all these organisms belong to the protist kingdom. Kingdom Protista (pruh TIHS tuh) contains many different types of organisms that share more characteristics with each other than with members of any other kingdom. All of the **protists** have a nucleus and therefore are eukaryotic. Some protists are one-celled, and others are many-celled. None share the complex organization found in plants and animals. Some protists contain chlorophyll and make their own food and others don't. Protists are plantlike, animal-like, and funguslike.

Most scientists think that protists evolved from the monerans because protists, although simple, are more complex in structure than monerans. Bacteria are thought to be the ancestors of animal-like and funguslike protists because these organisms can't make their own food. Plantlike protists probably evolved from cyanobacteria because both produce their own food.

Scientists hypothesize that protists are ancestors of the fungi, plant, and animal kingdoms. Plantlike protists, such as green algae, are the most probable ancestors of plants. Animal-like protists, the protozoa, are hypothesized to be the ancestors of animals because they have so many animal characteristics. Knowledge of the evolution of protists is incomplete because many lack hard parts and, as a result, there aren't very many fossils of these organisms.

Figure 9-1. Kingdom Protista is made up of a diverse group of organisms.



Plantlike Protists

Plantlike protists are known as **algae.** Some species of algae are one-celled and others are many-celled. All algae can make their own food because they contain the pigment chlorophyll in their chloroplasts. Remember pigments are colored materials that absorb certain wavelengths of light. Chlorophyll is a green pigment. Even though all algae have chlorophyll, not all of them look green. Many have other pigments that cover up their chlorophyll. Species of algae are grouped into phyla mainly according to their pigments and the form in which they store food. There are six main phyla of algae. Each phylum has its own unique characteristics.

Euglenas

Algae that belong to the phylum Euglenophyta have characteristics of both plants and animals. A typical euglena is the bright green *Euglena gracilis,* shown in Figure 9-2. Like plants, these one-celled algae have chloroplasts and produce carbohydrate as food. When light is not present, euglenas can be heterotrophs. Although euglenas have no cell walls, they do have a strong, flexible layer inside the cell membrane that helps them move and change shape. Many move by using flagella. Another animal-like characteristic of euglenas is that they have an adaptation called an eyespot that responds to light. The reddish eyespot helps the euglena locate light it needs to produce food by photosynthesis.

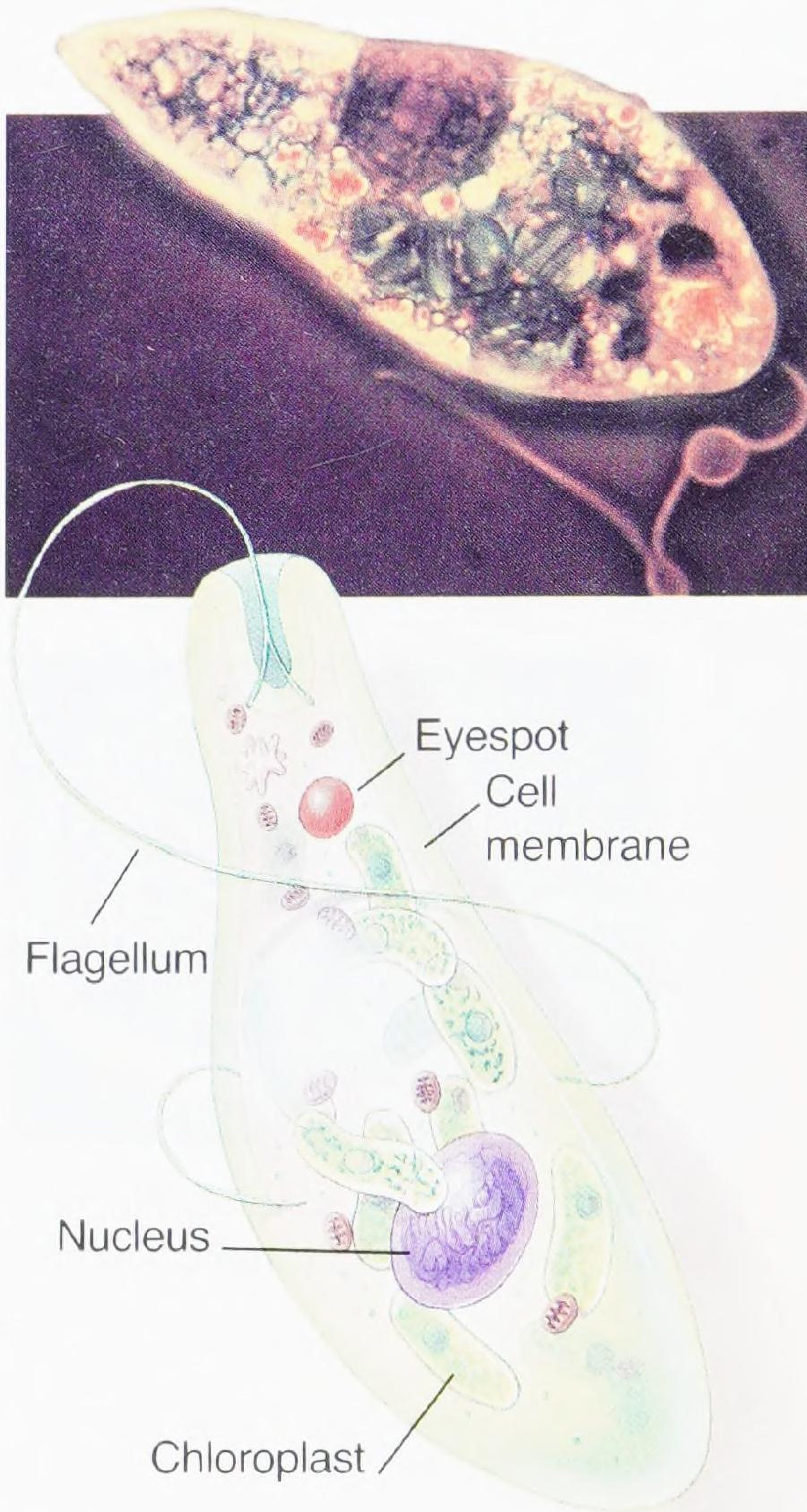


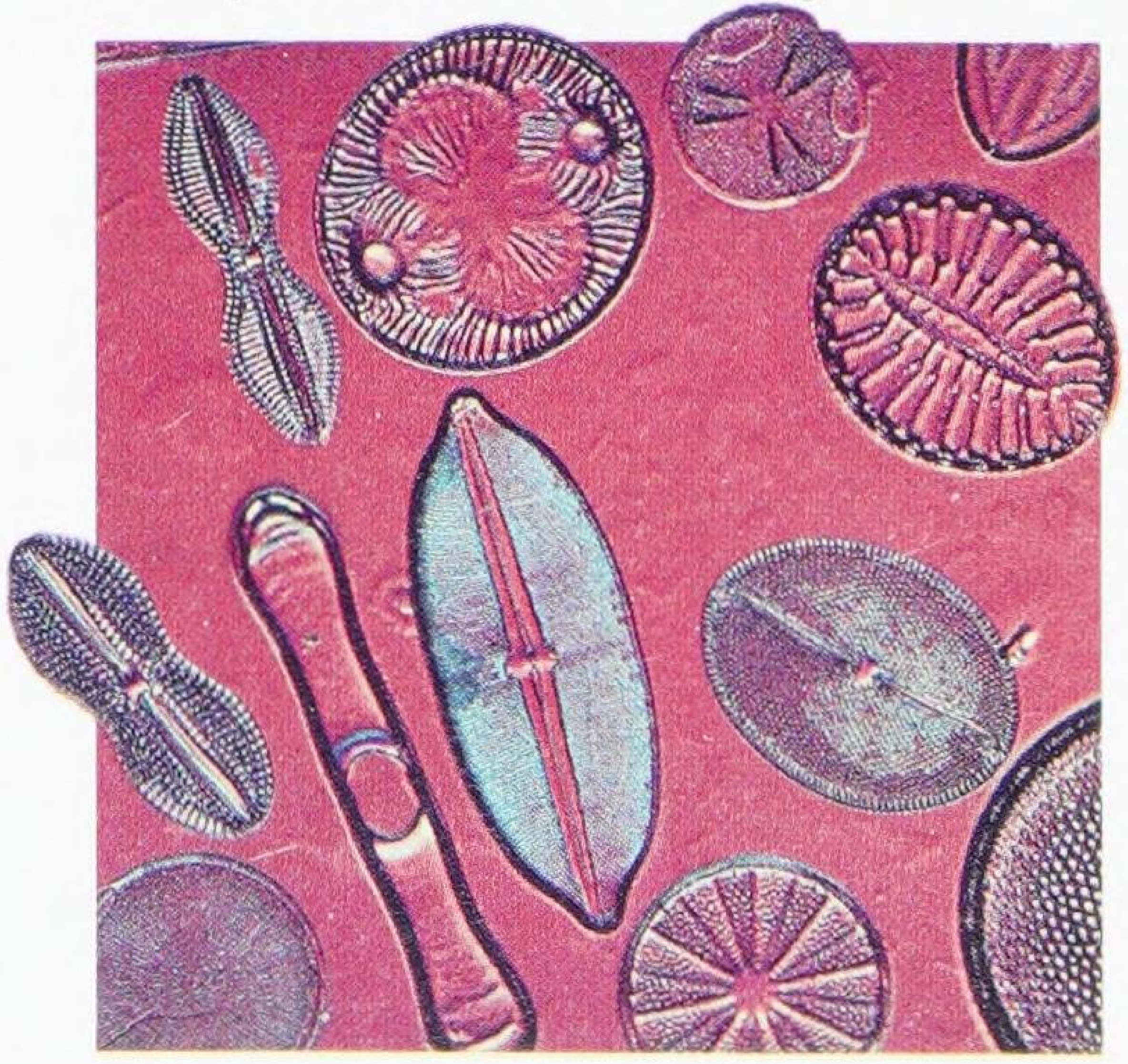
Figure 9-2. Euglenas are protists that have both plantlike and animal-like characteristics.

Diatoms

The most numerous of all the algae are the diatoms. They belong to the phylum Chrysophyta (kruh SAHF uh tuh). *Chryso* means "golden brown." Diatoms are photosynthetic one-celled algae that store food in the form of oil. They have a golden-brown pigment that masks the green chlorophyll. The shells of diatoms contain silica, the main element in glass. The body of a diatom is like a small box with a lid. One half of the shell fits inside the other half. Diatom shells are covered with markings and pits that form patterns.

You can find diatoms living in both freshwater and saltwater habitats. They are an important food source for many aquatic organisms.

Figure 9-3. The glassy cell walls of diatoms are covered with many beautiful markings.



Diatoms reproduce in unbelievably large numbers. When the organisms die, their small shells sink to the floor of the body of water and collect in very deep layers. Deposits made of these diatoms are mined with power shovels and used in insulation, filters, and road paint. Diatom shells produce the sparkle that makes road lines visible at night.

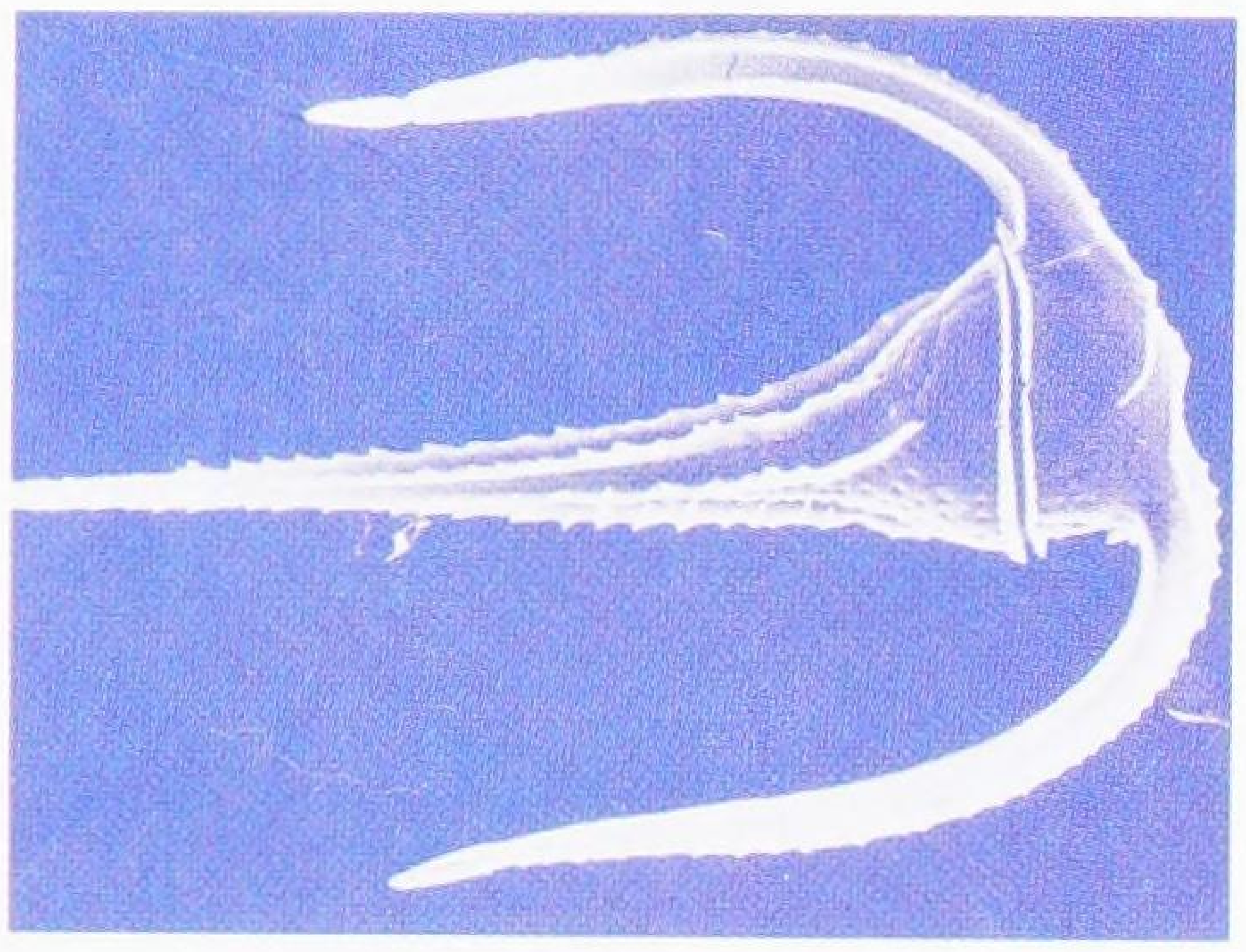


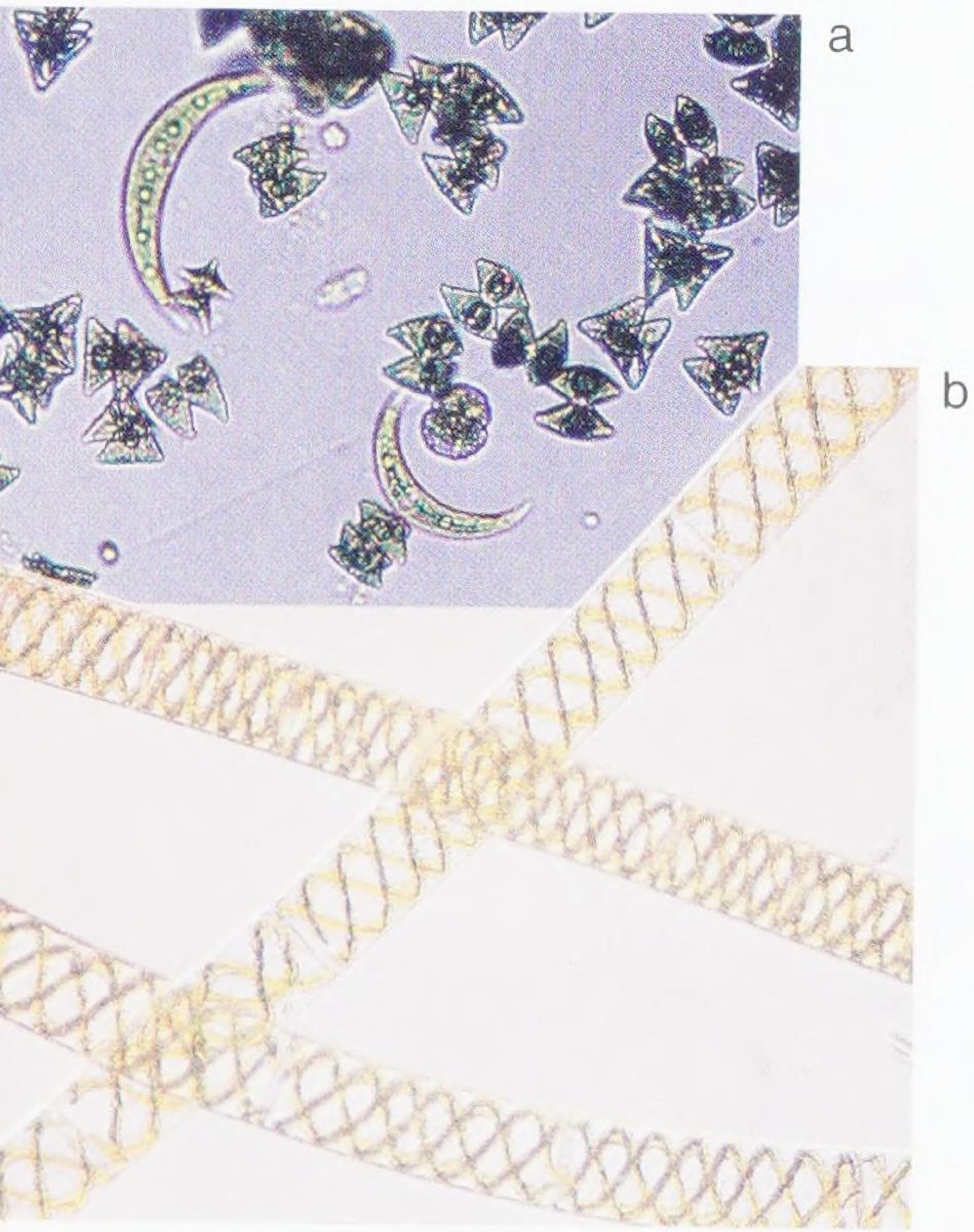
Figure 9-4. A scanning electron micrograph of a dinoflagellate.

Dinoflagellates

Phylum Pyrrophyta (puh RAHF uh tuh), the "fire" algae, contains species of one-celled algae called dinoflagellates that have red pigments. The name *dinoflagellate* means "spinning flagellates." One of the flagella moves the cell, and the other circles the cell, causing it to spin with a motion similar to a top. Dinoflagellates store food in the form of starch and oils.

Almost all dinoflagellates live in salt water. They are important food sources for many saltwater organisms. For unknown reasons, every once in awhile the population of certain species of dinoflagellates increases very rapidly. Red pigments in these algae cause the water to look red. This explosion of algae is known as a "red tide." Some dinoflagellates that cause red tides contain a nerve poison that can kill fish. People who eat fish or shellfish that have absorbed the poisons produced by these algae can also become ill and sometimes die.

Figure 9-5. There are many different shapes among the species of green algae. Phytoplankton (a) and *Spirogyra* (b) are shown here.



Green Algae

Species of green algae form the phylum Chlorophyta (kloh RAHF uh tuh). The presence of chlorophyll in green algae tells you that they undergo photosynthesis and produce food in the form of starch. Figure 9-5 shows different forms of green algae. Although most green algae live in water, others can live in many other environments, including trunks of trees and even on other organisms! Green algae can be one-celled or many-celled. *Chlamydomonas* is an example of a one-celled green alga. *Ulva,* also called sea lettuce, is a many-celled saltwater alga that grows in thin sheets. Many-celled species of green algae can be either chainlike or form colonies. *Spirogyra* is a chainlike freshwater alga that has spiral-shaped chloroplasts. *Volvox* is a freshwater form that occurs in ball-shaped colonies. The colony rolls through the water using its flagella.

Red Algae

The red algae belong to the phylum Rhodophyta (roh DAHF uh tuh). *Rhodo* means "red" and describes the color of members of this phylum. If you've ever eaten pudding, or used toothpaste, you have eaten something made with red algae! A carbohydrate called carrageenan found in red algae is used to give toothpaste and pudding their smooth, creamy textures. Most red algae are many-celled. Some species of red algae can live up to 175 meters deep in the ocean. Their red pigment allows them to absorb the limited amount of light that penetrates to those depths and enables them to produce a type of starch.

Brown Algae

Brown algae make up the phylum Phaeophyta (fee AHF uh tuh). Members of this phylum are many-celled and vary greatly in size. Large brown algae called kelps may be as much as 100 meters long. Many kelps are important food sources for fish and invertebrates. They form a dense mat of stalks and leaflike blades where many small fish and other animals live.

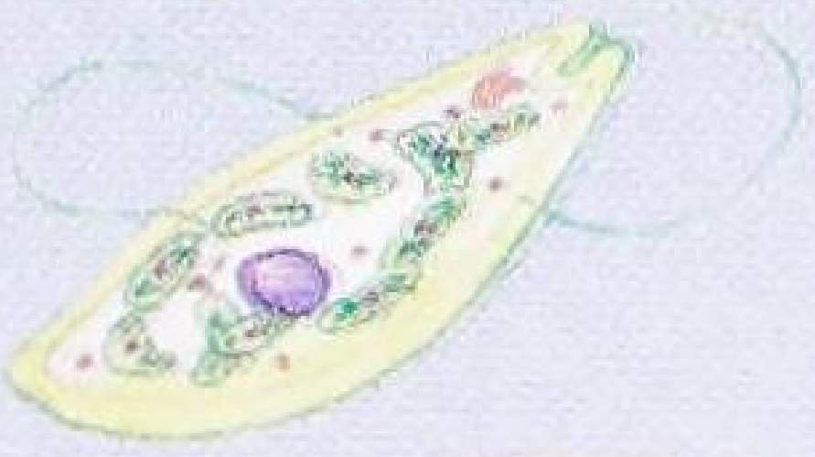
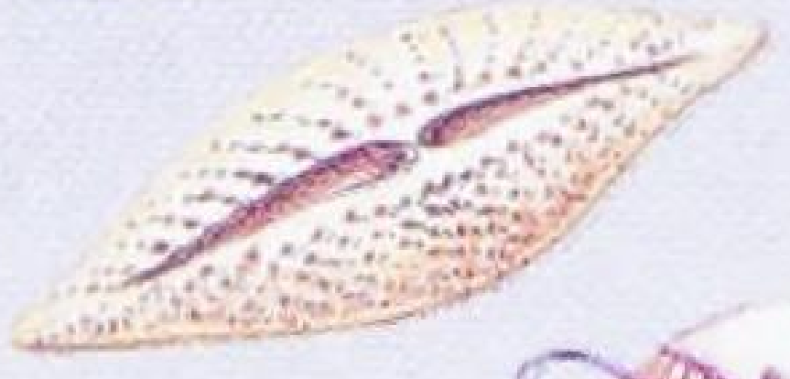
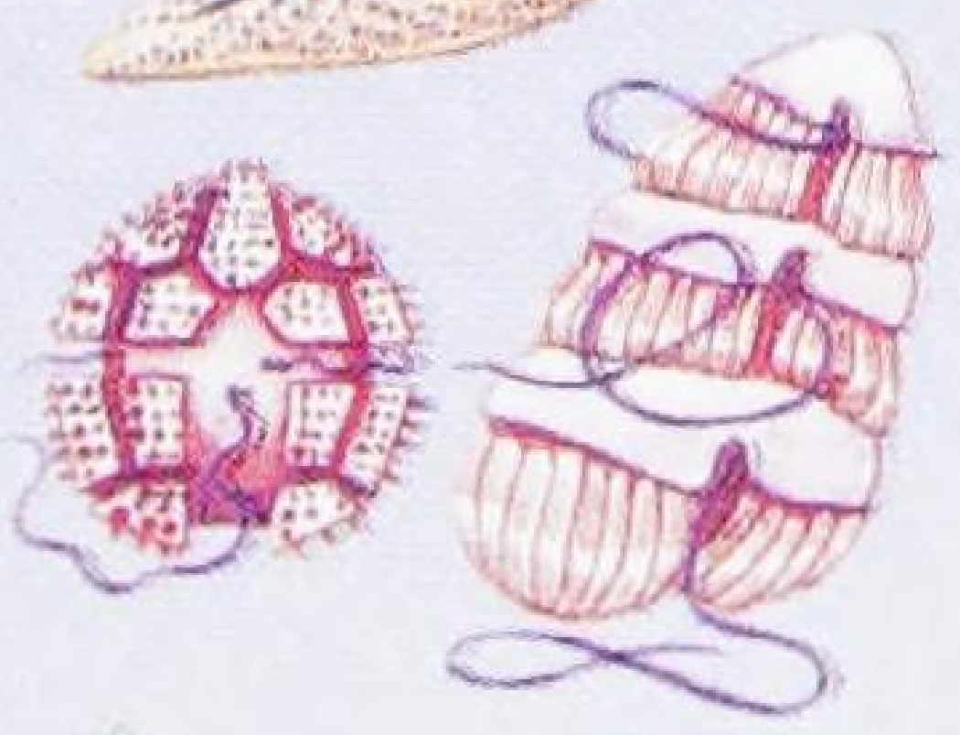
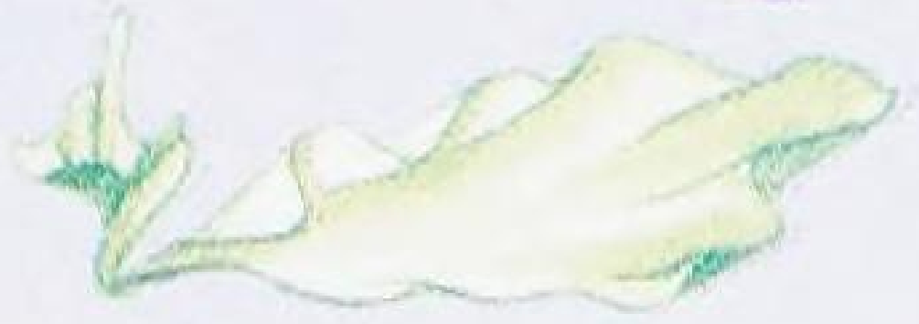
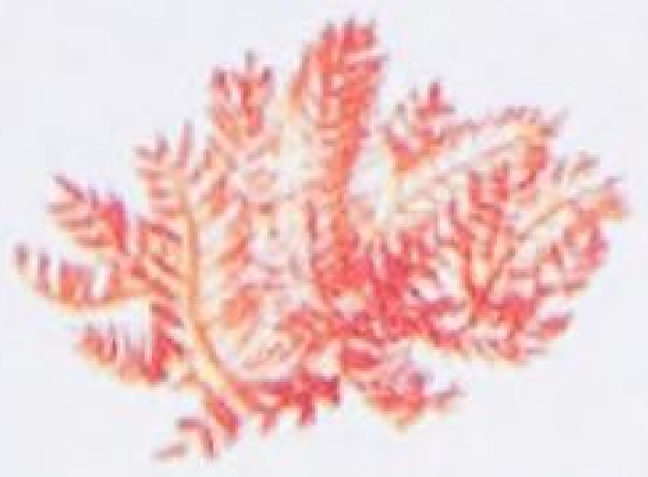
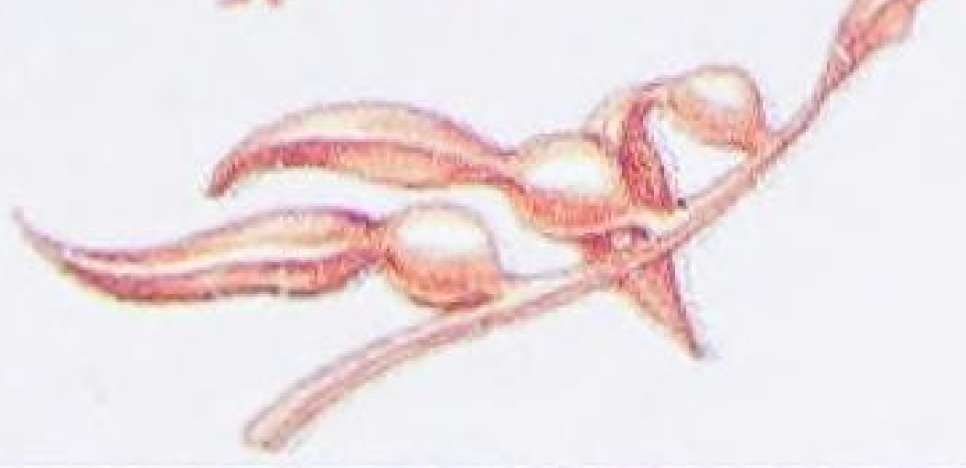
People in many parts of the world eat brown algae. The thick texture of food such as ice cream and marshmallows is produced by a carbohydrate called algin found in this alga. Brown algae are also used to make fertilizer.

In Your JOURNAL

Choose one species of plantlike protist and imagine that you become that protist for a day. **In your Journal**, after researching the protist, describe what your day as a protist might be like.

Table 9-1

THE PLANTLIKE PROTISTS

Phylum	Example	Pigments	Other Characteristics
Euglenophyta Euglenas		Chlorophyll	One-celled algae that move with a flagellum; has eyespot to detect light.
Chrysophyta Diatoms		Golden Brown	One-celled algae with body made of two halves. Cell walls contain silica.
Pyrrophyta Dinoflagellates		Red	One-celled algae with two flagella. Flagella cause cell to spin. Some species cause red tide.
Chlorophyta Green Algae		Chlorophyll	One- and many-celled species. Most live in water, some live out of water, in or on other organisms.
Rhodophyta Red Algae		Red	Many-celled algae; carbohydrate in red algae is used to give some foods a creamy texture.
Phaeophyta Brown Algae		Brown	Many-celled algae, most live in salt water; important food source in aquatic environments.

Animal-like Protists

One-celled animal-like protists are known as **protozoa** (proht uh ZOH uh). These complex organisms live in water, soil, and dead organisms. Many types of protozoans are parasites. Remember that a parasite is an organism that lives in or on another organism. The parasite harms the other organism. In addition to the usual cell organelles, protozoans contain special vacuoles for digesting food and getting rid of excess water. Four species of protozoan are classified based on method of movement.

Sarcodines

The first protozoans were probably similar to members of the phylum Sarcodina (sar kuh DI nuh). The *Amoeba* shown in Figure 9-6 is a typical species of this phylum. Sarcodines move about and feed using temporary bulges of their cytoplasm called **pseudopods** (SEWD uh pahdz). The word *pseudopod* means "false foot." Pseudopods are footlike extensions of cytoplasm the organism uses to move and to trap food. An amoeba extends the cytoplasm of a pseudopod on either side of a bit of food such as a bacterium. The two ends of the pseudopod close like two fingers. As the fingers of cytoplasm close, the bacterium is trapped. A vacuole forms around the food and it is digested. Sarcodines are found in freshwater or saltwater environments and in other animals as parasites. You may have heard that it isn't wise to drink water in certain countries. This is because many areas of the world have a species of amoeba in the water that can cause dysentery. Dysentery can induce a severe form of diarrhea.

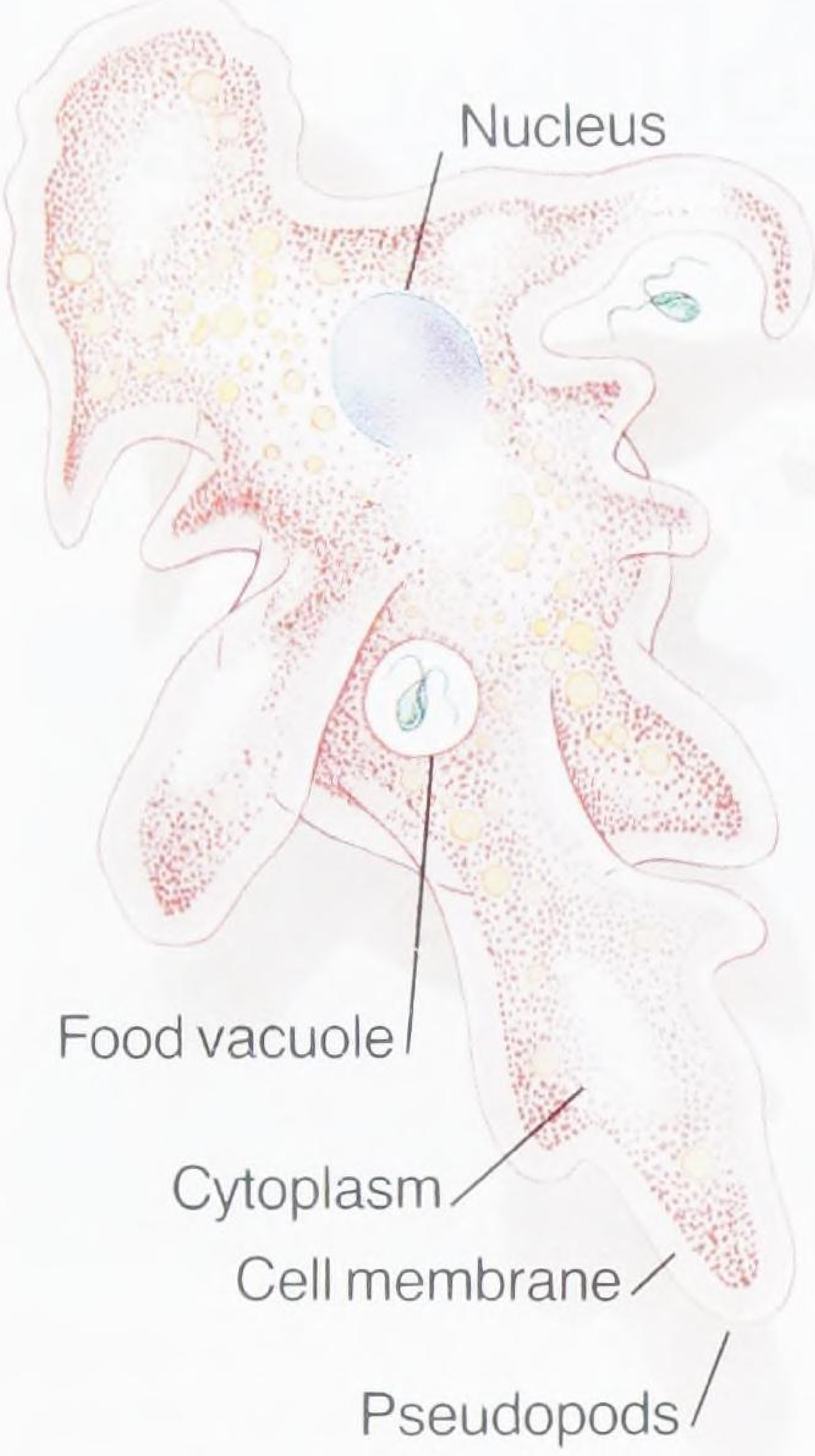
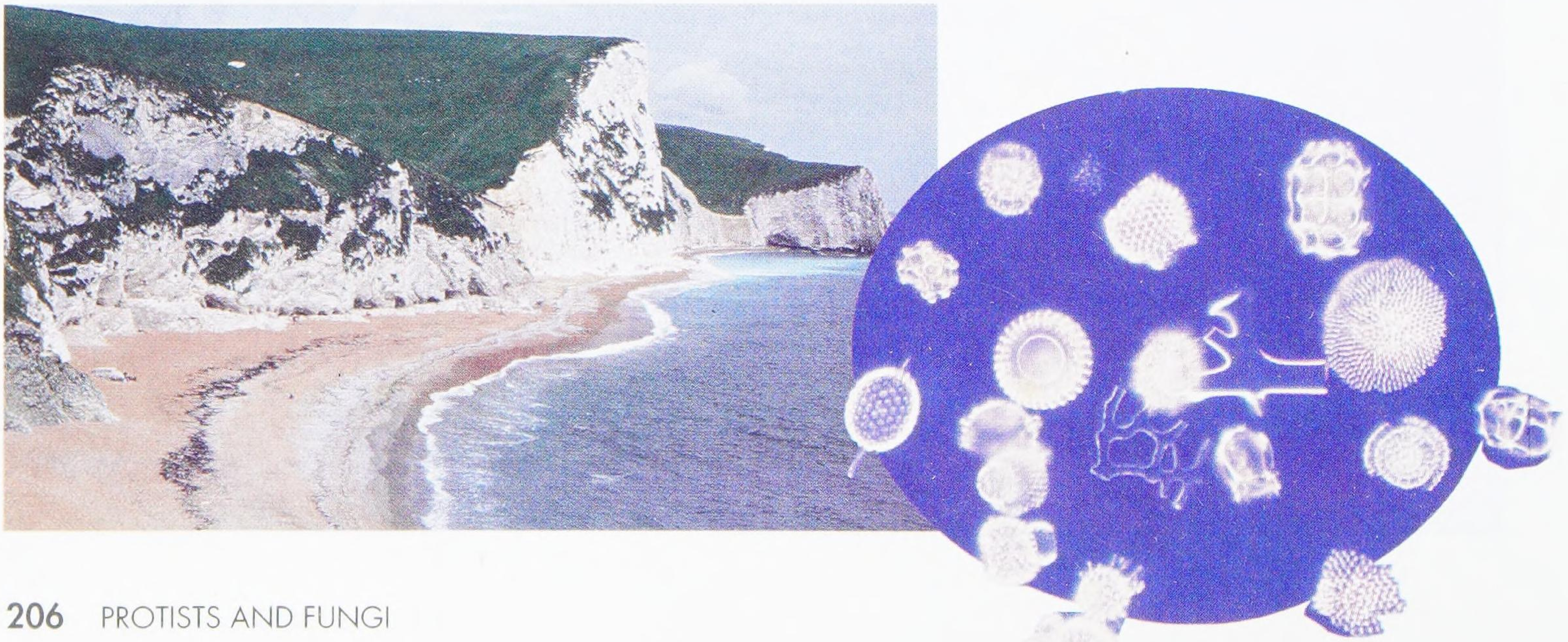


Figure 9-6. An amoeba constantly changes shape as it forms pseudopods.

Figure 9-7. Many of the saltwater sarcodines have skeletons made of a chalklike material called calcium carbonate. The White Cliffs of Dover in England are made almost entirely of the shells of billions of these organisms. The photo at the right shows the shells of some sarcodines.



Flagellates

Protozoans that move using flagella are called flagellates (FLAJ uh layts) and belong to the phylum Mastigophora (mas tuh GAHF uh ruh). All of the flagellates have one or many long flagella that whip through a watery environment, moving the organism along. Many species of flagellates live in fresh water, but some are parasites.

Trypanosoma is a flagellate that causes African sleeping sickness in humans and other animals. It is spread by the tsetse fly in Africa. The disease causes fever, swollen glands, and extreme sleepiness. Another flagellate lives in the digestive system of termites. These flagellates are beneficial to the termites, because they produce enzymes that digest the wood the termites eat. The termites can't digest the wood without the flagellates.

Connect to... Chemistry

Some termites feed on above-ground buildings or structures made from wood and trees. These termites are completely dependent on their intestinal protozoans for survival. If these protozoans were all removed from a termite, it would continue to feed, but would eventually starve to death. What carbohydrate in wood do the protozoans break down?

Ciliates

The most complex protozoans belong to the phylum Ciliophora. Members of this phylum move by using cilia. **Cilia** are short, threadlike structures that extend from the cell membrane. Ciliates may be covered with cilia, or have cilia grouped in special areas of the cell. The beating of the cilia is organized so the organism can move swiftly in any direction.

A typical ciliate is *Paramecium* in Figure 9-8. In the *Paramecium* you can see another characteristic of the ciliates: they have two nuclei, a macronucleus, and a micronucleus. The large macronucleus controls the everyday functions of the cell. The smaller micronucleus functions in reproduction. Paramecia usually feed on bacteria swept into the oral groove. Once the food is inside the cell, a food vacuole forms and the food is digested. The contractile vacuole removes excess water from the cell. Wastes are removed through the anal pore.

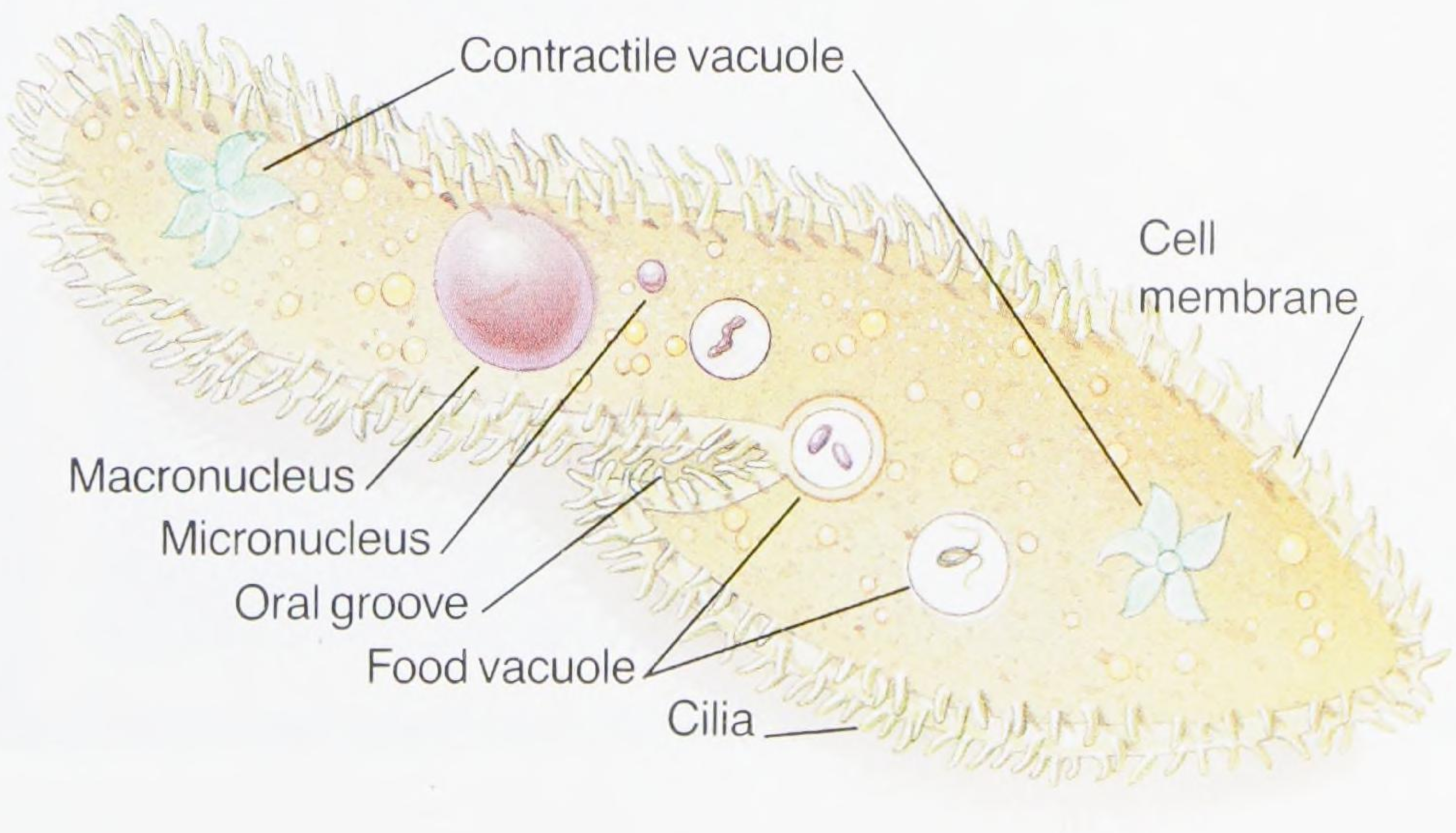


Figure 9-8. *Paramecium* is a typical ciliate.

Figure 9-9. Female *Anopheles* mosquitoes spread the sporozoan that causes malaria.

Sporozoans

The phylum Sporozoa contains only small, parasitic protozoans. Sporozoans have no way of moving on their own. All are parasites that live in and feed on the blood of humans, and other animals.

Figure 9-9 shows a mosquito that carries *Plasmodium,* a sporozoan common in tropical climates. This sporozoan causes malaria in humans. Malaria is spread when an infected mosquito bites a human. There is no vaccine for malaria. It causes many deaths each year.

Funguslike Protists

Funguslike protists include several small phyla of protists that have features of both protists and fungi. Slime molds and water molds are funguslike protists. Slime molds are much more attractive than their name sounds. Many are very brightly colored. They form a delicate weblike structure on the surface of their food supply. They obtain energy by decomposing organic materials.

PROBLEM SOLVING

Puzzled about Slime

Stan and his cousin, Aaron, were walking through the woods near Stan's home when Stan discovered an orange mass on a fallen log. Stan told Aaron it was slime mold. His class had been studying protists, and he had seen some slime mold at school. He had read that slime molds were classified in the protist kingdom because they are similar to amoebas, using pseudopods to move and ingest food.

Aaron said, "You're wrong. My textbook classifies slime molds in the fungus kingdom. Slime molds have reproductive structures just like fungi."

The two boys were puzzled as to why slime molds were placed in the protist kingdom in one book and in the fungus kingdom in another. What evidence is there that slime molds are protists?

Think Critically: Why do some scientists classify slime molds as protists and others classify them as fungi?

Slime Molds

Slime molds like the one pictured in Problem Solving have some protozoan characteristics. During part of their life cycle, the cells of slime molds move by means of pseudopods and behave like amoebas. Slime molds reproduce with spores the way fungi do. You will learn about reproduction in fungi in the next section.

Although most slime molds live on decaying logs or dead leaves in moist, cool, shady woods, one common slime mold is sometimes found crawling across lawns and mulch. It creeps along feeding on bacteria and decayed plants and animals. When conditions become less favorable, reproductive structures form on stalks, and spores are produced.

MINI-Lab

What do slime molds look like?

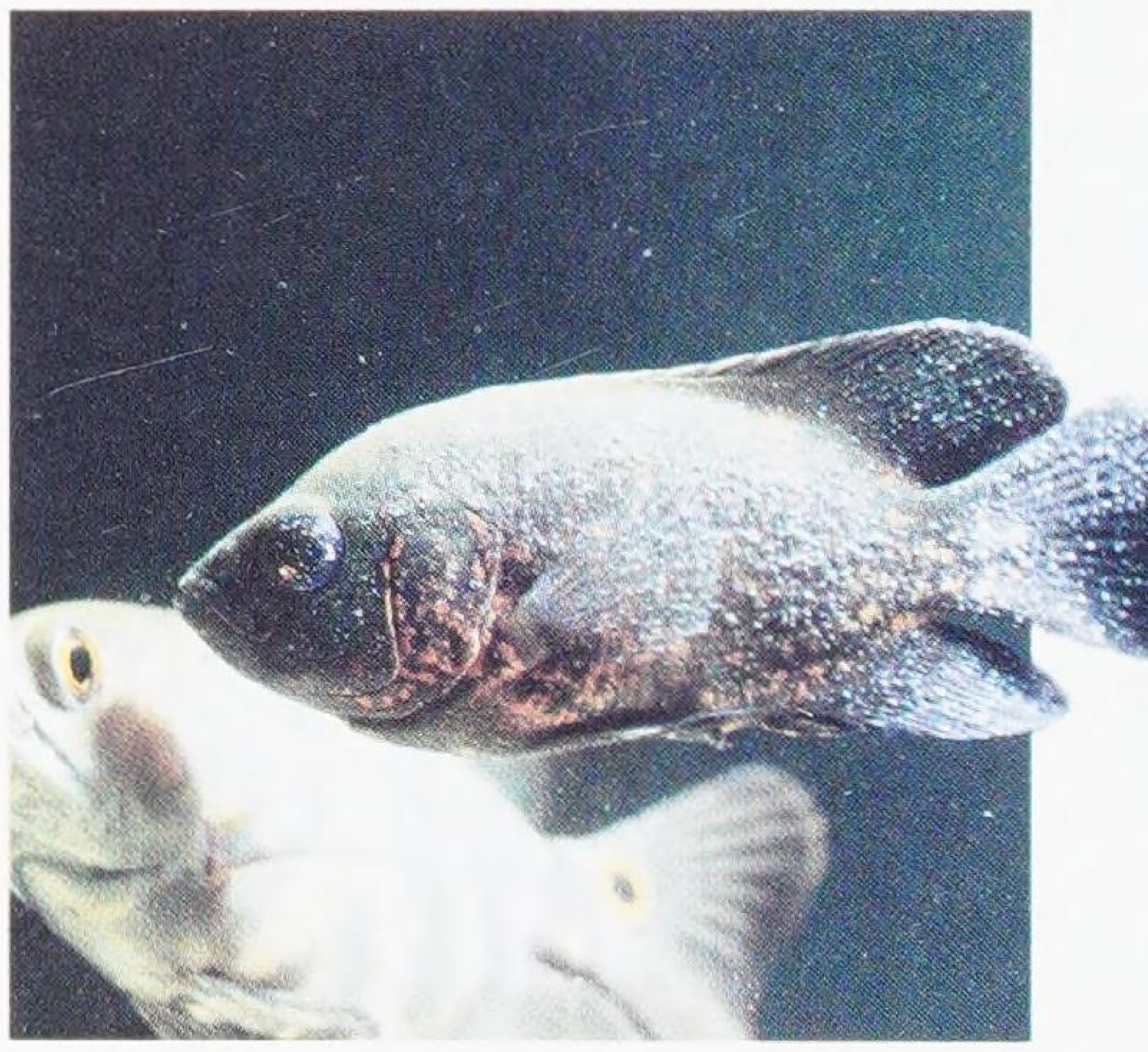
Obtain materials for growing the slime mold *Physarum* from your teacher. Follow the instructions for growing the mold. **In your Journal,** make daily drawings and observations of the mold as it grows. *Predict* the conditions under which the slime mold would change from the amoeboid form.

Water Molds and Mildew

Water molds, downy mildews, and white rusts make up another phylum of funguslike protists. The most well-known member of this phylum is the water mold that caused the Irish potato famine in 1846 and 1847. Potatoes were Ireland's main crop and the main food source for the people. Nearly two million people died in the famine.

Water molds have cell walls as do fungi, but their relatively simple cells are more like those of protozoans. Figure 9-10 shows a parasitic water mold that grows on decaying fish. If you have an aquarium, you may see water molds attack a fish and cause its death.

Figure 9-10. A parasitic water mold growing on a fish.



SECTION REVIEW

1. What are the main characteristics of all protists?
2. Describe the characteristics of the three groups of protists.
3. **Apply:** Why aren't there many fossils of the different groups of protists?
4. **Connect to Earth Science:** Find out what plankton is, where it is located, and what protists are in plankton.

Skill Builder

Making and Using Tables

Make a table that compares the characteristics of the four phyla of protozoans. Include phylum, example species, mode of locomotion, and other characteristics. If you need help, refer to Making and Using Tables in the **Skill Handbook** on page 690.

ACTIVITY 9-1

Comparing Algae and Protozoa

Problem: *What are the differences between algae and protozoans?*

Materials

- cultures of *Paramecium, Amoeba, Euglena, Spirogyra,* and *Micrasterias*
- prepared slide of slime mold
- 5 coverslips
- microscope
- dropper
- 5 microscope slides

Procedure

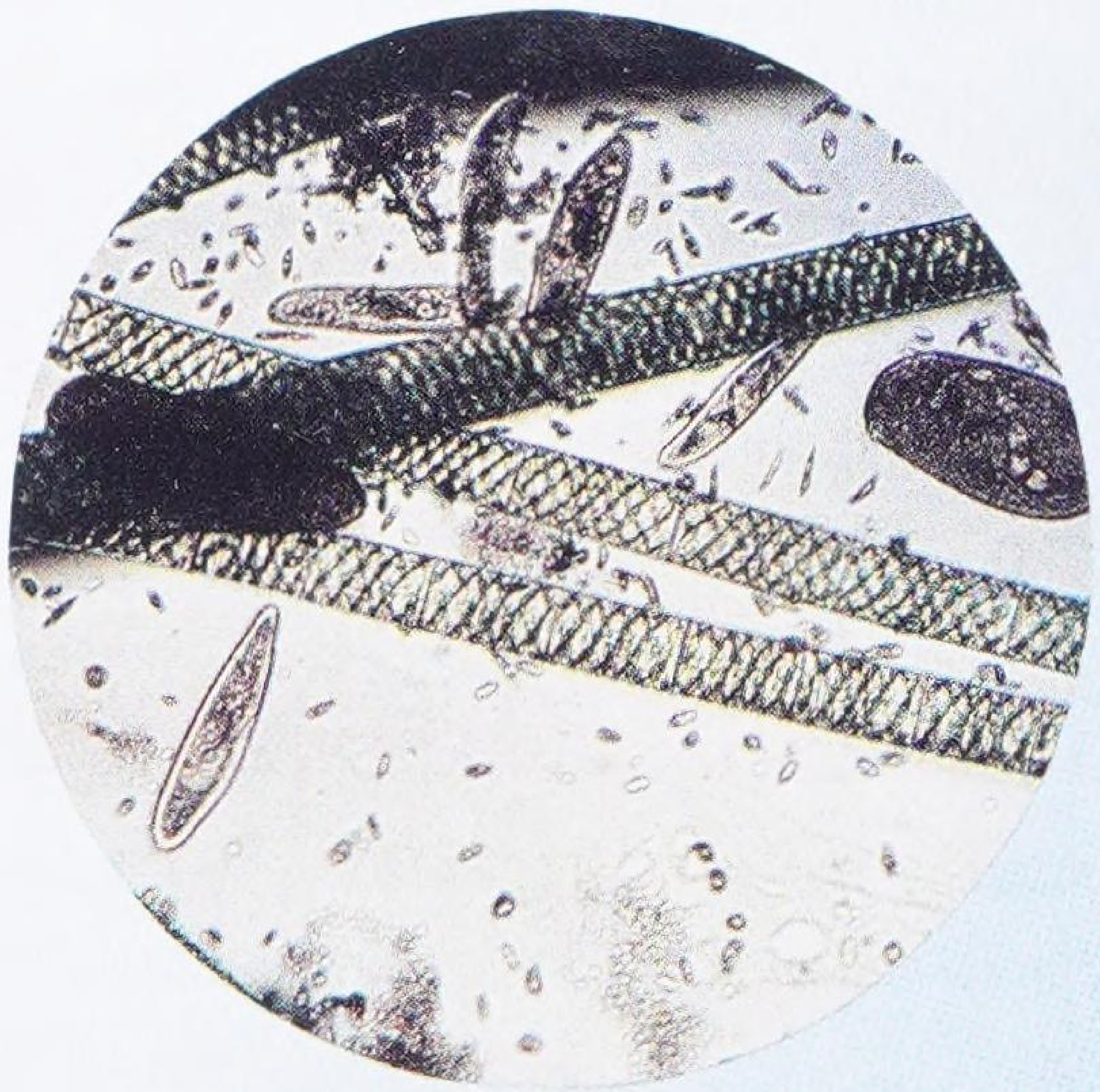
1. Make a data table **in your Journal** for your drawings and observations.
2. Make a wet mount of the *Paramecium* culture.
3. Observe the wet mount first under low and then under high power. Draw and label the organism.
4. Repeat Steps 2 and 3 with the other cultures. *Return all preparations to your teacher and wash your hands.*
5. *Observe* the slide of slime mold under low and high power. *Record* your observations.

Analyze

1. For each organism that could move, label the structure that enabled the movement.
2. Which protists could not move? Why?
3. Describe whether each protist had one cell or many cells.

Conclude and Apply

4. Which protists make their own food? *Explain* how you know that they make their own food.
5. Which protists had animal characteristics?
6. Which protists had fungus characteristics?



Data and Observations

	Paramecium	*Amoeba*	*Euglena*	*Spirogyra*	*Micrasterias*
Drawing					

Kingdom Fungi

9-2

Objectives

- Identify the characteristics shared by all fungi.
- Classify fungi into groups based on their methods of reproduction.
- Describe the difference between the imperfect fungi and all other fungi.

New Science Words

hyphae
chitin
spores
sporangia
asci
budding
basidium
lichen
symbiosis
mutualistic

What Are Fungi?

Do you believe you can find members of Kingdom Fungi in a quick trip around your house or apartment? Well, you probably can. You can find fungi in your kitchen if you have canned mushrooms, mushroom soup, or fresh mushrooms. You may also find mold, a type of fungus, growing on an old loaf of bread, or mildew, another fungus, growing on your shower curtain. Yeasts are a type of fungi used to make bread, cheese, beer, and wine.

As important as fungi seem in the production of different foods, they are most important in their role as organisms that decompose or break down organic materials. Food scraps, clothing, dead plants, and animals are all made of organic material. Fungi work to decompose, or break down, all these materials and return them to the soil. The materials returned to the soil are then reused by plants. Fungi, along with bacteria, are nature's recyclers. They keep Earth from becoming buried under mountains of waste materials.

Fungi were once classified as plants. But, unlike plants, fungi do not make their own food or have the specialized tissues and organs of plants. You will learn about plant structures in the next unit. Most species of fungi are many-celled. The body of a fungus is usually a mass of many-celled, threadlike tubes called **hyphae** (HI fee). The mat of hyphae is called a mycelium (mi SEE lee um). The cell walls of hyphae are made of **chitin,** a strong, flexible carbohydrate that is also found in the body covering and wings of insects.

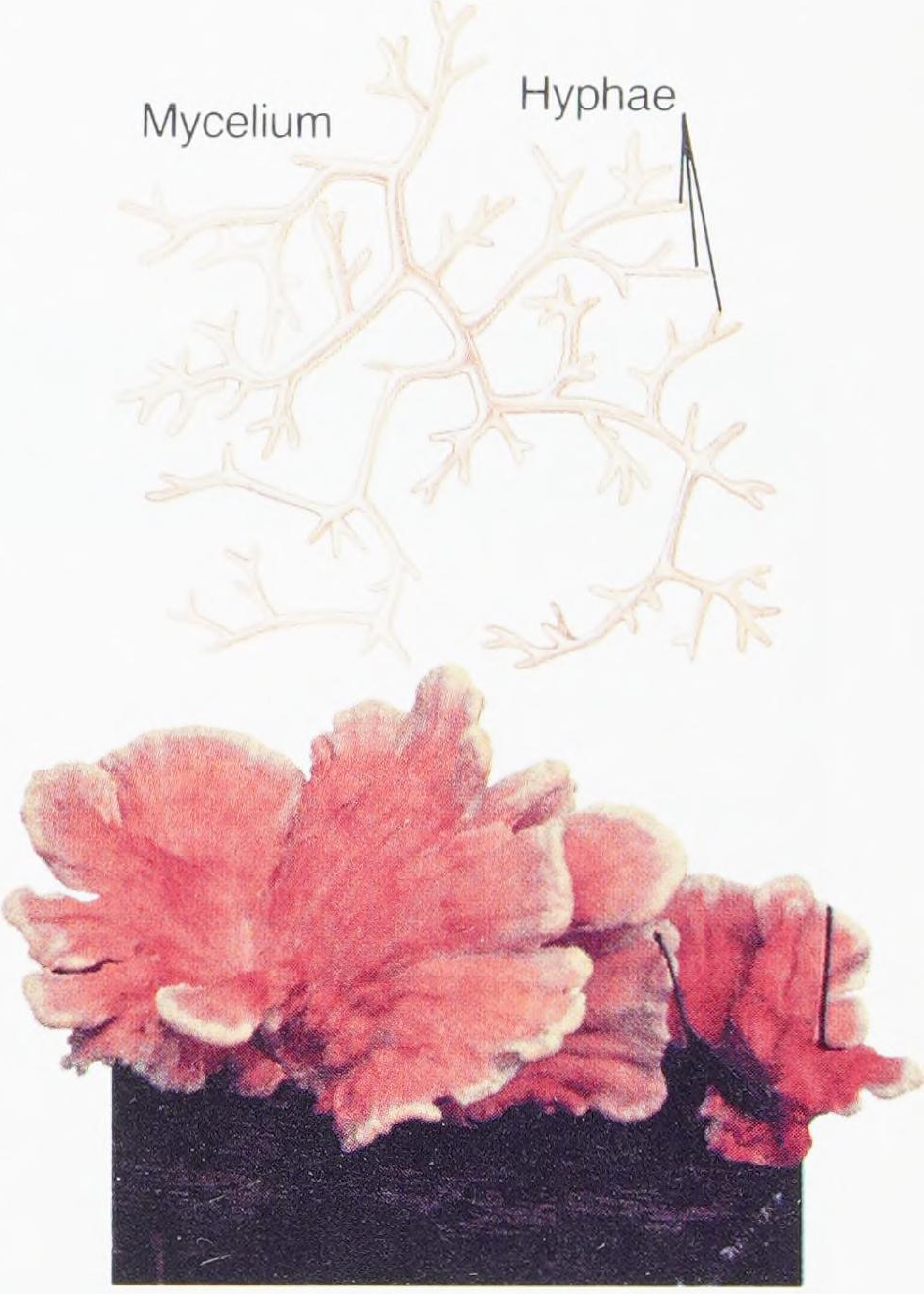


Figure 9-12. A fungus is made up of many threadlike tubes called hyphae.

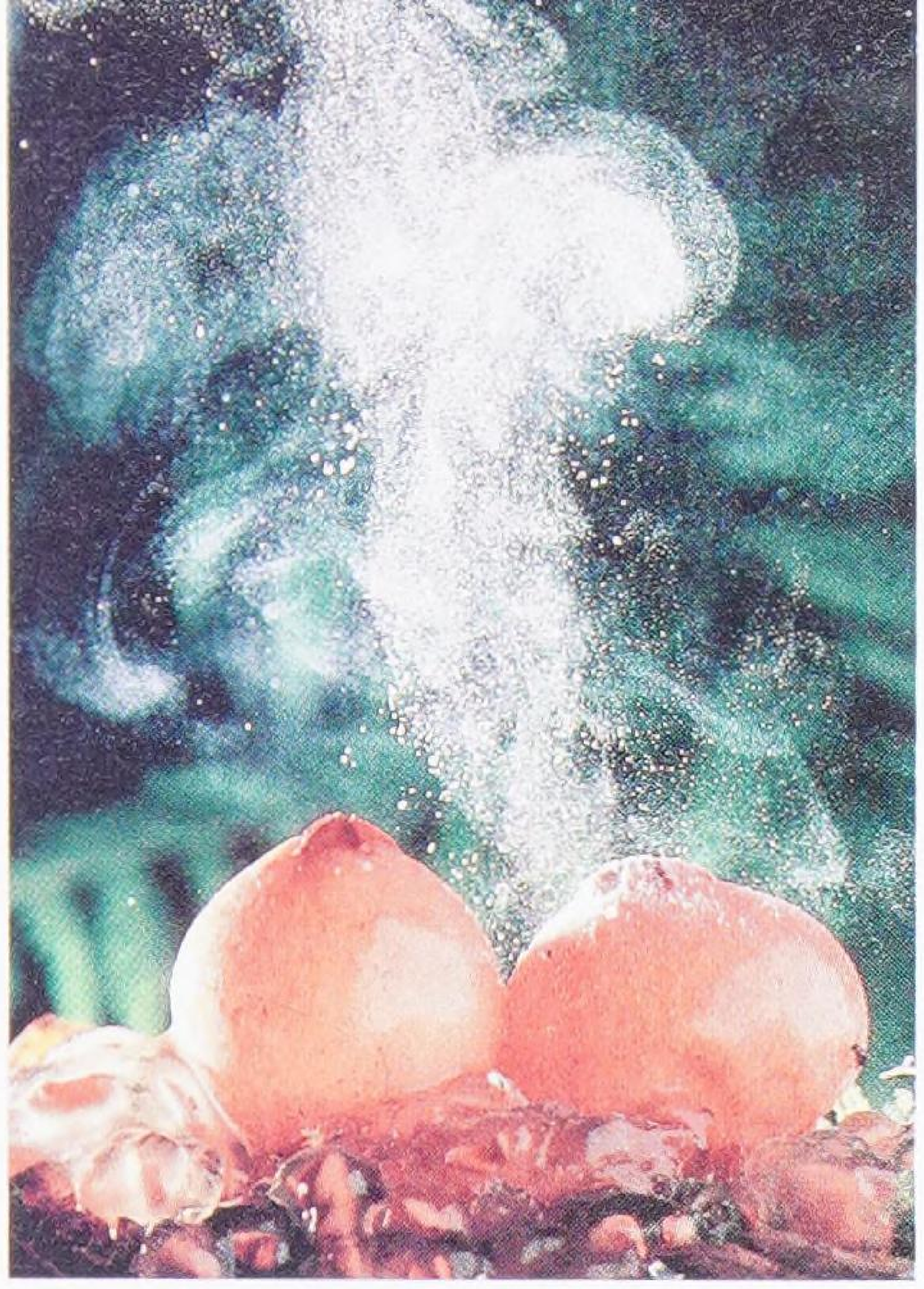


Figure 9-12. Fungi reproduce by spores. This puffball mushroom releases many spores at once.

Fungi don't contain chlorophyll and can't make their own food. Most fungi feed on dead organisms. Organisms that obtain food in this way are called saprophytes. A fungus secretes enzymes to digest food outside of itself. Then the fungus cells absorb the digested food. Fungi that cause athlete's foot and ringworm are parasites. They obtain their food directly from living things.

Fungi grow best in warm, humid areas. Moist places such as tropical regions of the world or the spaces between your toes are homes for many types of fungi.

Look at the mushroom in Figure 9-12. The puff of "smoke" above it is actually made of the structures fungi use for reproduction, spores. **Spores** are reproductive cells that form new organisms without fertilization. The structures in which fungi produce spores are used to classify fungi into one of four divisions.

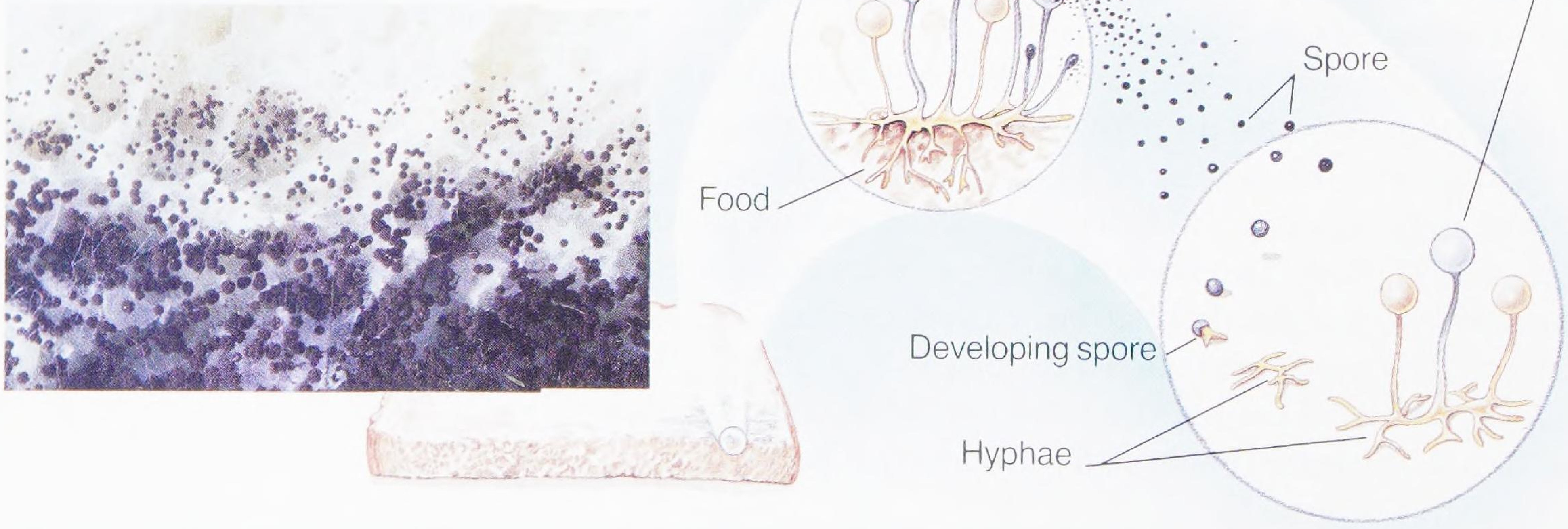
Divisions of Fungi

Zygote Fungi

How are fungi classified?

The fuzzy black mold that you sometimes find growing on an old loaf of bread is a type of zygote fungus. Fungi that belong to this division, the division Zygomycota (zi goh mi KOH tuh), produce spores in round spore cases called **sporangia** on the tips of upright hyphae. The sporangia turn black as they mature. The black fuzz you see on the bread is actually a mass of mature spore cases. When each sporangium splits open, hundreds of spores are released into the air. Each spore will grow into more mold if it lands where there is enough moisture, a warm temperature, and a food supply.

Figure 9-13. In zygote fungi, spores are produced in round black spore cases on the tips of upright hyphae. The photo shows the zygote fungus *Rhizopus* growing on bread.



Sac Fungi

Yeasts, molds, morels, and truffles are all examples of sac fungi. The spores of these fungi are produced in little sacs called **asci.** The division Ascomycota is named for these sacs. The ascospores are released when the tip of an ascus breaks open.

Many sac fungi are well known by farmers because they destroy plant crops. Diseases caused by sac fungi are Dutch elm disease, apple scab, and ergot disease of rye.

Yeast is an economically important sac fungus. Yeasts don't always reproduce by forming spores. They also reproduce asexually by budding. **Budding** is a form of asexual reproduction in which a new organism grows off the side of the parent. Yeasts are used in the baking industry. As yeasts grow, they use sugar for energy and produce alcohol and carbon dioxide as waste products. The carbon dioxide causes bread to rise. All the little holes you see in a slice of bread were formed from little bubbles of carbon dioxide produced by yeast.

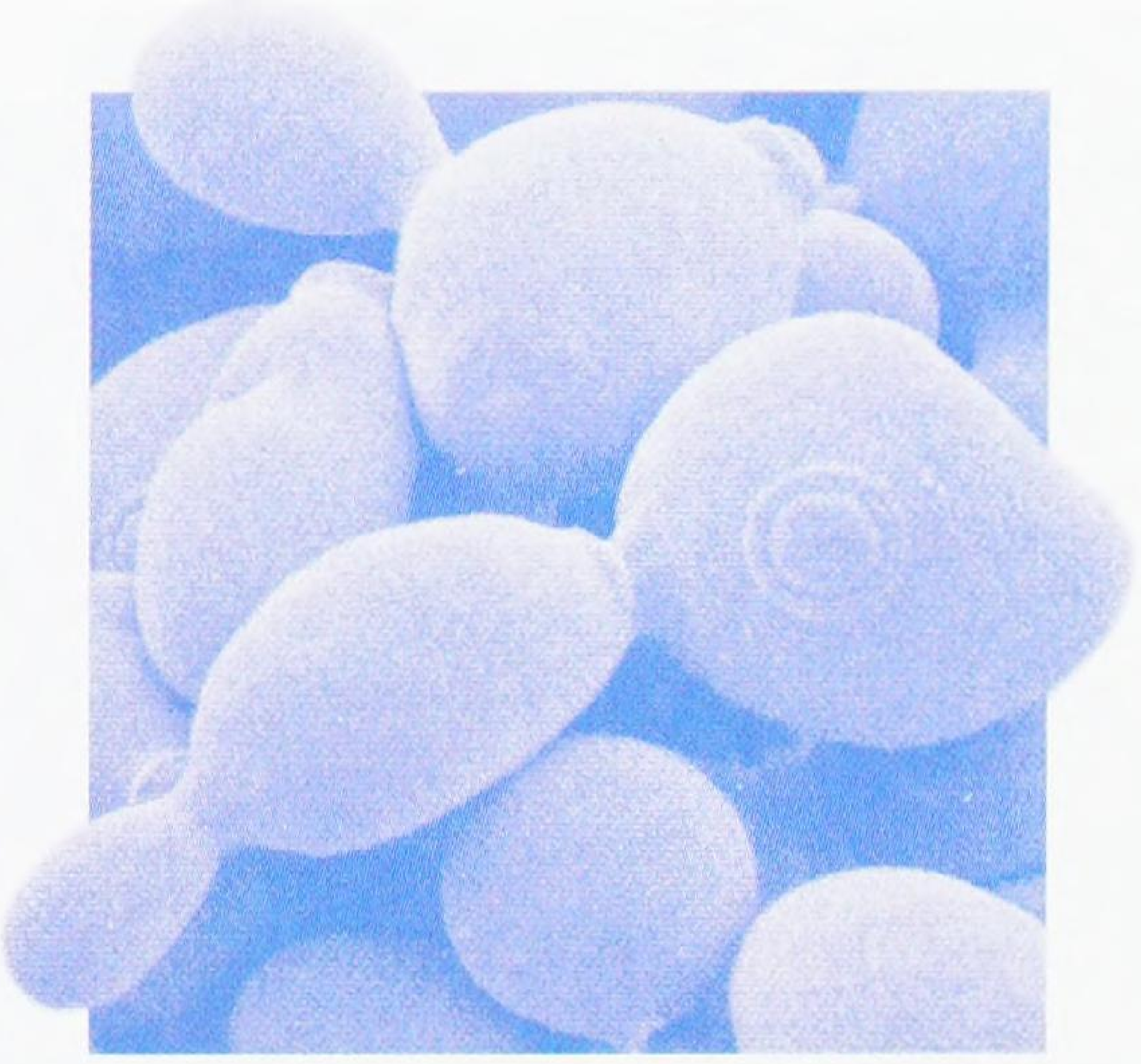


Figure 9-14. Yeasts can reproduce by forming buds off the side of the parents. The bud pinches off and forms an identical cell.

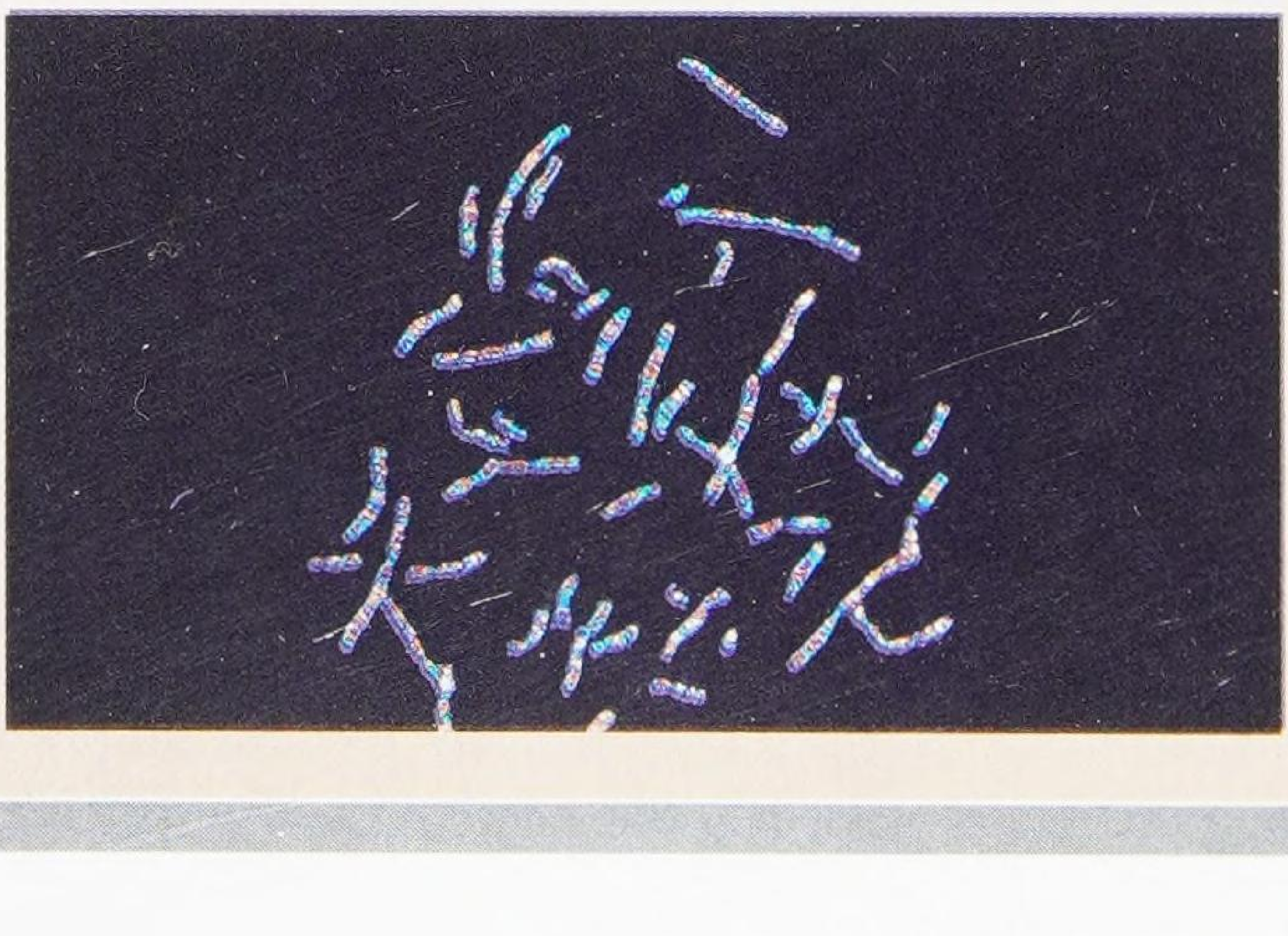
TECHNOLOGY

A Yeast Library

Scientists have a goal to map the entire human DNA pattern, or genome, within fifteen years. Surprisingly, yeast may be an important tool. The genome maps the order of all the bases in human DNA and allows scientists to locate a particular gene on a specific piece of DNA. The gene can then be analyzed to find the exact bases involved and their order. Yeast artificial chromosomes (YAC) are providing a library for storing human DNA segments.

Human DNA is cut into pieces, and these pieces are inserted into yeast chromosomes. Scientists then try to reorder the DNA as it would appear on a human chromosome and map the nucleotide bases present. YACs are useful because one YAC holds more than ten times as many bases as other artificial chromosomes. The longer the sequence of bases in a segment, the easier it is to piece segments together. The most complete YAC collection of human DNA contains 60 000 YACs.

Think Critically: How would knowing the human genome help us?



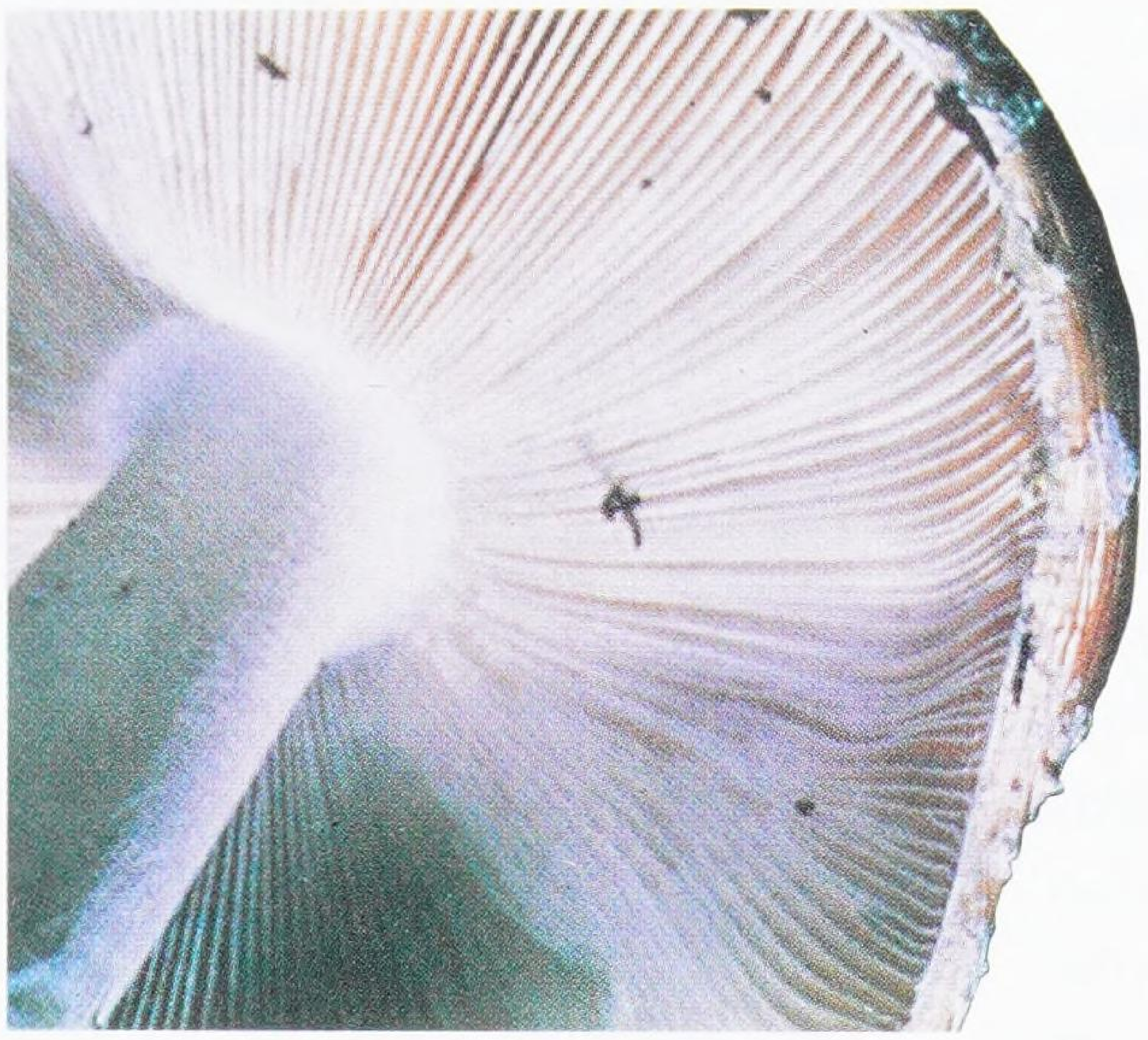
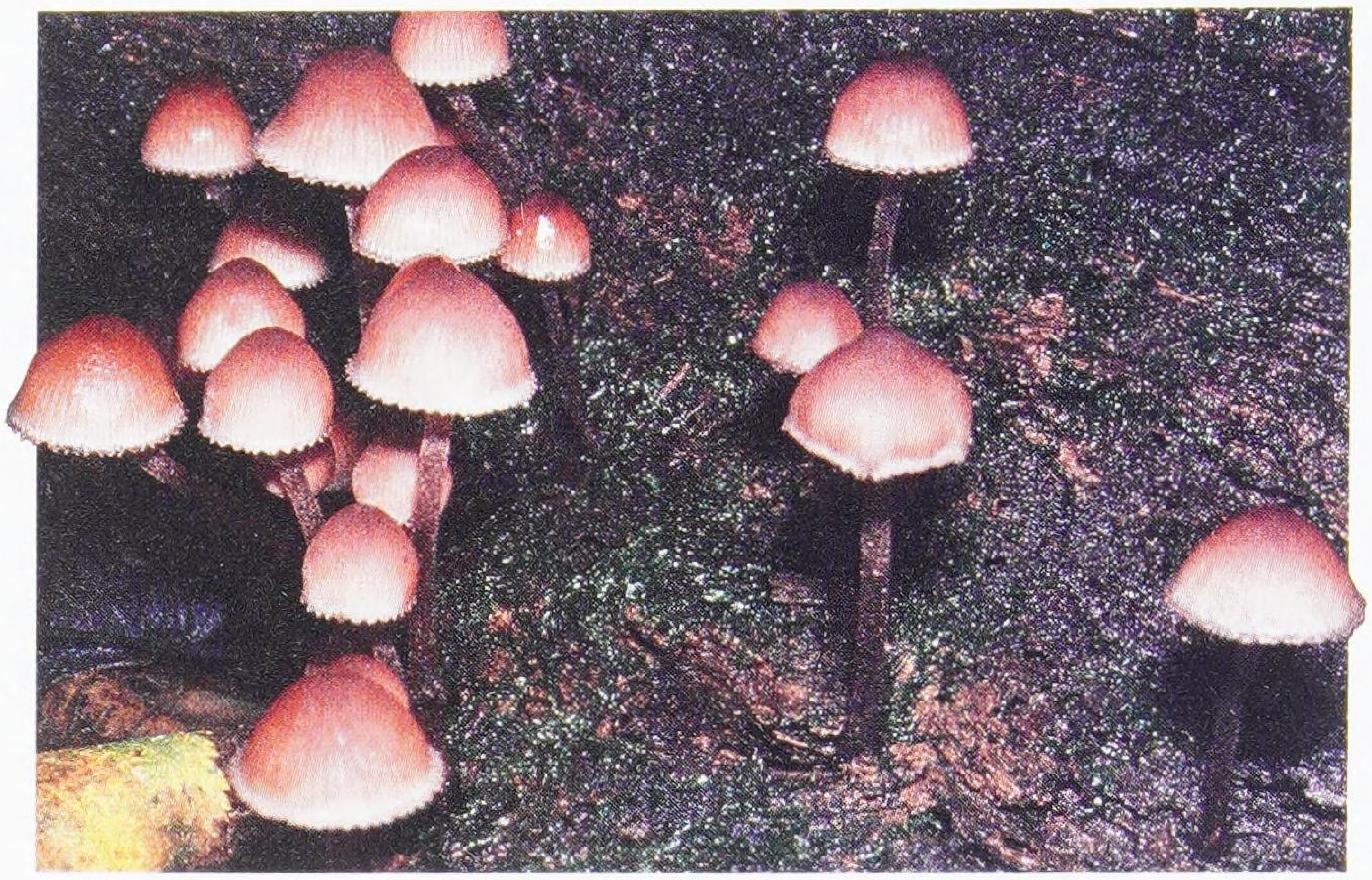


Figure 9-15. A mushroom is the spore-producing structure of a club fungus. Spores are contained in many club-shaped structures that line the gills of a mushroom cap.



Club Fungi

The mushroom shown in Figure 9-16 is a member of the division Basidiomycota (buh SIHD ee uh mi koht uh). These fungi are commonly known as club fungi. The spores of these fungi are produced in a club-shaped structure called a **basidium.** Under the cap of a mushroom, the reproductive structure of the fungus, are thin sheets of tissue called gills. The tiny club-shaped structures line the gills. The spores you observed on the gills of the mushroom in the Find Out activity at the beginning of this chapter were produced in the basidia. Puffball mushrooms, mushrooms you eat on pizza, and bracket, or shelf, fungi that grow on the trunks of trees are all club fungi.

Many of the club fungi are economically important. Rusts and smuts damage billions of dollars of food crops each year. Mushrooms are an important food crop, but you should never eat a wild mushroom because many are poisonous. Even experts at fungi identification sometimes find it difficult to tell the difference between edible and poisonous mushrooms. Mistakes in identification can be fatal.

MINI-Lab

How are spore prints made?

Obtain several mushrooms from the grocery store. Let them age several days until the undersides look very brown. Remove the stems and arrange the mushrooms caps down on a white paper towel. Be sure the gills are against the paper towel. Let them sit undisturbed overnight. Lift the mushrooms from the paper towel. What do you see? What made the marks? How could you *estimate* the number of new mushrooms that could come from this one cap?

Imperfect Fungi

When the sexual stage of a fungus is observed, the species is immediately classified as one of the other three phyla. The imperfect fungi, division Deuteromycota, is composed of species of fungi in which a sexual stage has never been observed. *Penicillium* is one example from this group. Penicillin, an antibiotic, is an important product of these fungi. Other examples of imperfect fungi are species that cause ringworm and athlete's foot.

Lichens

The colorful organisms in Figure 9-16 are lichens. A **lichen** is an organism that is made of a fungus and green alga or a cyanobacterium. When two organisms live together, they often have a symbiotic relationship. **Symbiosis,** a close relationship between two organisms, can have several results. The fungus and cyanobacterium, or green alga, both benefit from living together, and they are said to have a **mutualistic** relationship.

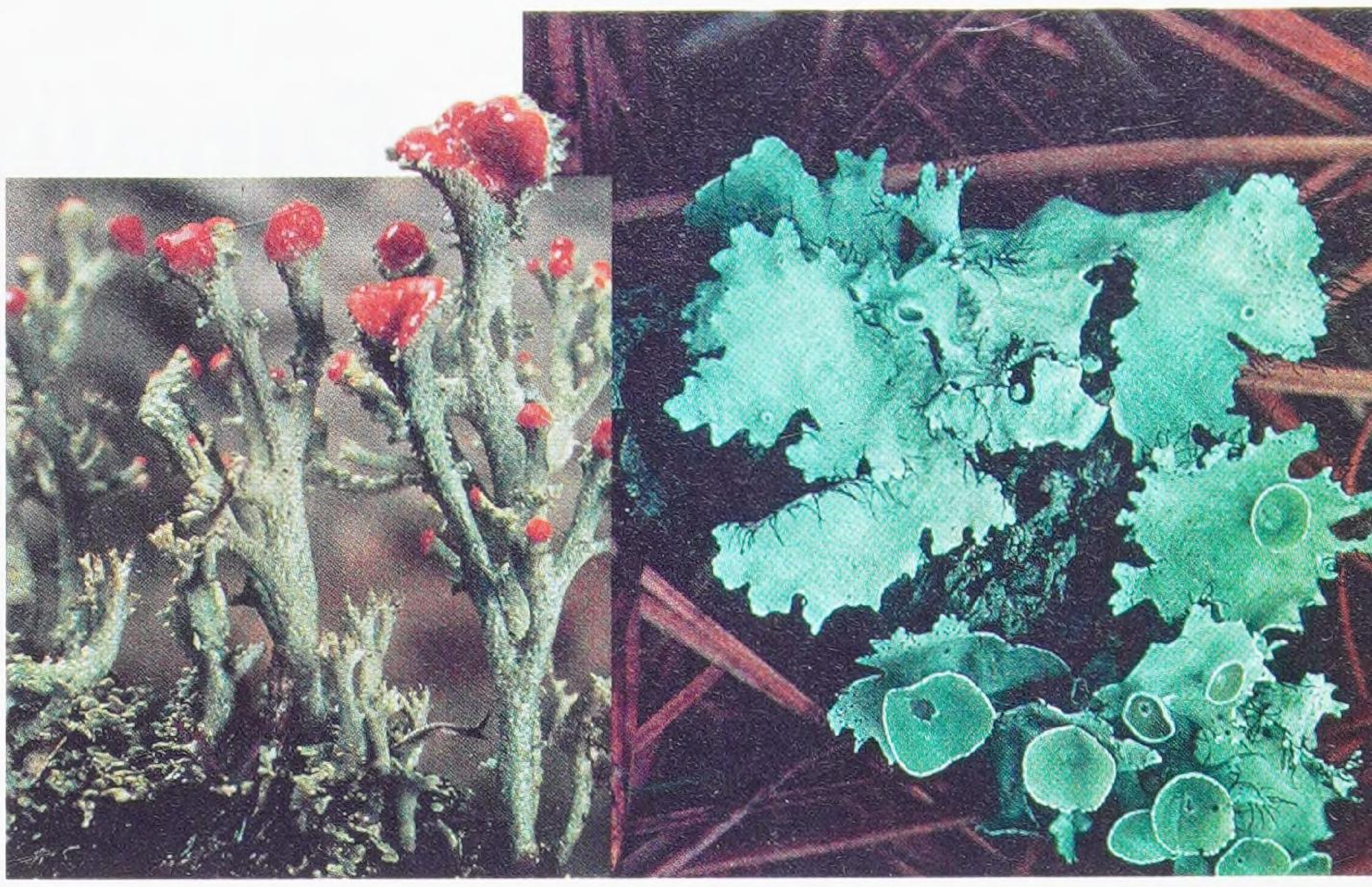


Figure 9-16. Lichens can grow upright, like the British soldier lichen (left), or appear leafy (right). Some other forms grow flat, much like a crust.

The cells of the alga live tangled up in the threadlike strands that make up the fungus. The alga gets a moist, protected place to live, and the fungus gets food from the alga.

Lichens are an important food source for many animals. Reindeer and caribou feed on reindeer moss, a lichen that grows in arctic regions. Many lichens are easily affected by air pollution. Lichen growth on tree trunks and stone buildings can be used to monitor pollution levels.

Connect to... Earth Science

Lichens are often the first organisms to colonize bare rock. For this reason, lichens are called pioneer species. Pioneer species release acids as a part of their metabolism. **Hypothesize** the effect of pioneer species on rock.

SECTION REVIEW

1. How do fungi obtain food?
2. Why are Ascomycota called sac fungi?
3. In a lichen, how do both the fungus and cyanobacterium or alga benefit from living together?
4. **Apply:** If an imperfect fungus were found to produce basidia under some circumstances, how would the fungus be reclassified?
5. **Connect to Physics:** How do air currents help in the spread of fungi?

Using Variables, Constants, and Controls

Skill Builder

In an experiment, yeasts were cultured at different temperatures in a particular concentration of syrup and water. Different amounts of carbon dioxide were produced at each temperature. Identify the constant and variables in this experiment. If you need help, refer to Using Variables, Constants, and Controls in the **Skill Handbook** on pages 686-687.

SCIENCE & SOCIETY

9-3 Fungus—Can't Live Without It

Objectives

- **State two types of drugs that are produced from fungi.**
- **Appreciate the role of fungi in medicine.**

Beneficial Fungi

Did you know that fungus has probably saved your life? In fact, this may have happened several times! Before the introduction of antibiotic drugs during the 1940s, many deaths occurred due to diseases caused by bacteria. It was common at that time for people to die of pneumonia, tuberculosis, and other infections. Today, however, antibiotics, chemicals that have a harmful effect on bacteria, are used to treat these infections. Many antibiotics are produced from fungi that grow in the soil. You have probably heard of penicillin, the most famous antibiotic. It is produced by a fungus, *Penicillium chrysogenum.* You may have seen this fungus growing on a moldy orange.

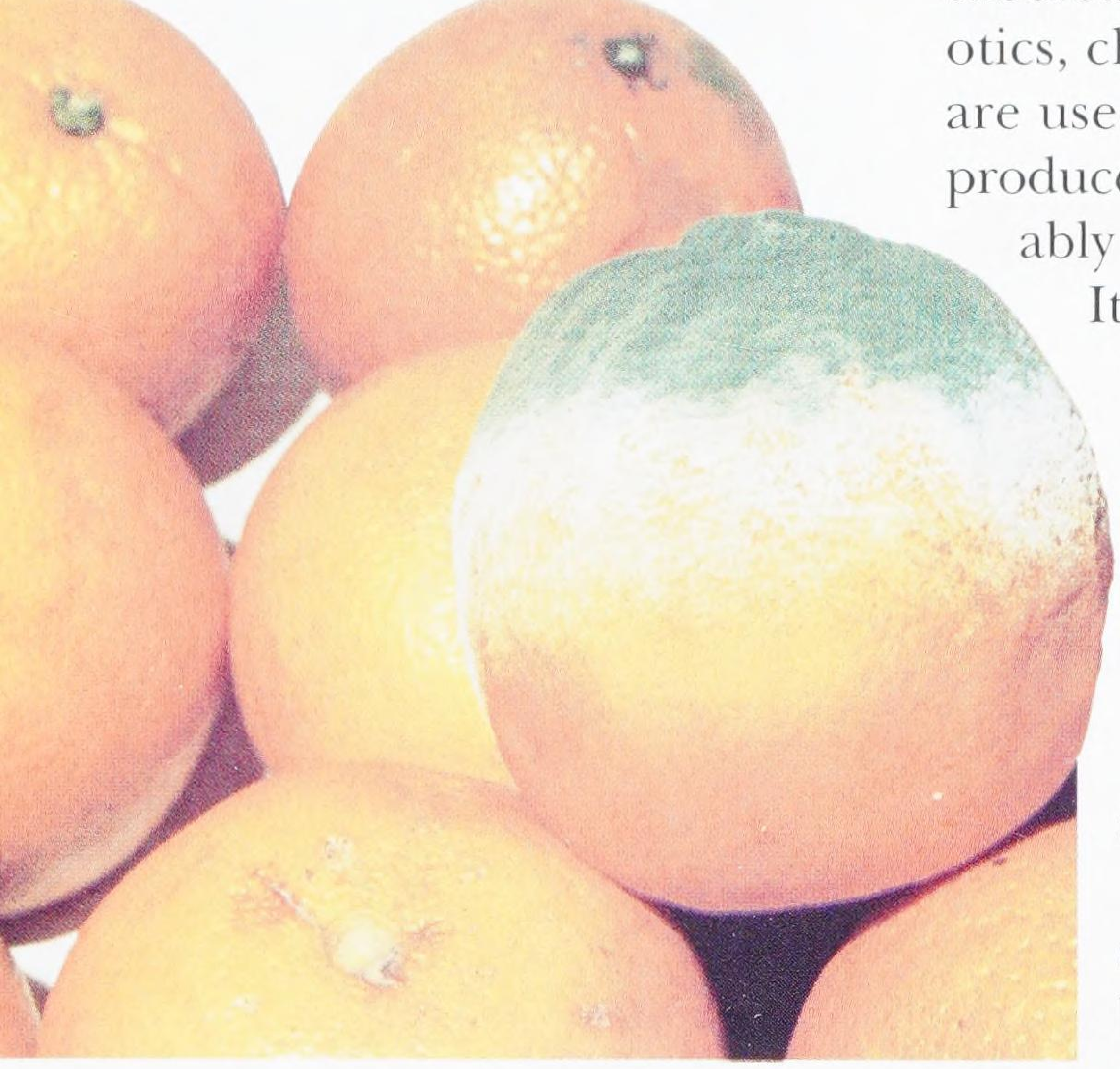


Figure 9-17. Penicillium grows easily on oranges.

Antibiotics prevent bacterial diseases by preventing bacteria from reproducing and growing. Most bacterial infections can be cured with antibiotics. Unfortunately, some people cannot be treated with certain antibiotics because of allergic reactions.

Now scientists face a new problem: bacteria are able to develop new strains that are not affected by antibiotics. For example, at one time, penicillin was effective against many types of bacteria. Today, it has no effect on most of these bacteria. Other antibiotics that have this same problem are streptomycin, tetracycline, and erythromycin. This keeps scientists working to develop new antibiotics to work against these harmful types of bacteria.

Antiviral drugs are used to treat infections caused by viruses. However, they were much more difficult to develop. This is because viruses do not have enzymes or organelles to destroy. Drugs developed to treat viral infections often resulted in being harmful to the patient as well.

Encephalitis is an inflammation of the brain, spinal cord, and the nerves leading from the spinal cord. It is carried by mosquitoes and can be deadly. In 1978, an antiviral drug, vidarabine, was finally approved by the United States Food and Drug Administration for treatment of encephalitis. This was the very first antiviral drug. It was produced from a species of fungi.

In 1983 another drug produced from fungi was approved for use. The drug cyclosporine was approved for use in organ transplant patients. Cyclosporine is made from an imperfect fungus. The drug helps prevent the rejection of transplanted organs. Because of cyclosporine, organ transplants have become routine. One problem is that the patient must take cyclosporine for life, and it can become expensive. It can also have some bad side effects, such as kidney failure.

Due to the great expense of research programs that were needed to develop these drugs, some people argue that more effort should be made to prevent these diseases rather than cure them. Encephalitis, for example, could be prevented by controlling the mosquitoes that transmit it. Society must work with science if such medical problems are to be prevented.

STERILE PENICILLIN G PROCAINE SUSPENSION

Figure 9-18. Antirejection drugs suppress the immune system, and must be taken daily.

SECTION REVIEW

1. State two types of drugs that are products of fungi.
2. Why have fungi become so important to medicine?
3. **Connect to Earth Science:** Find out where most fungi that produce antibiotics are usually found.

You Decide!

SCIENCE & SOCIETY

In the fall of 1990, there was an outbreak of encephalitis spread by mosquitoes in central and southern Florida. Health officials urged people to limit evening activities outdoors because mosquitoes are most active and feeding then. By keeping people away from the mosquitoes, they hoped to limit the spread of encephalitis. Why do you think it was important for people to stay away from the mosquitoes even though there is a drug to fight the disease? Would you have taken the advice of the health officials?

DESIGNING AN EXPERIMENT

ACTIVITY 9–2

Investigating Growing Conditions for Fungi

If you were to search for fungi, where would you expect to find them? What conditions do you think would be necessary? In this chapter, you learned that there are many kinds of fungi that grow in a variety of conditions. You would be most likely to be able to find bread mold or penicillin mold on fruit in your search at home. Would such fungi grow equally well on dry or moist bread; bread in the refrigerator or in the warmer bread box? In this activity, you will be the scientist and find out some conditions in which fungi grow best.

Getting Started

In preparation for designing your experiment answer the following questions:

1. What question are you investigating?
2. Will you study fungi that grow on bread or fruit?
3. What growth condition will you study?
4. What variables are important in this activity?

Safety Precautions

Always wash your hands after working with fungi. Wear a dust mask if you have allergies to mold spores.

Hypothesis

What is your hypothesis? What is your reason for forming this hypothesis? Share this information with your group. Choose a hypothesis that can be tested in the classroom.

Brainstorm

In your group, make a list of possible ways to test your hypothesis.

Experimental Plan

- Design your experiment to test only one variable. Make sure you plan to collect quantitative data.
- In a numbered list, similar to a recipe, make a set of directions that anyone can follow to do the experiment.
- Make a list of the materials and the quantities needed to do the experiment.

Answer the following questions

1. Have you included a control?
2. What will you measure?
3. How many food sources will you test?
4. How many conditions for each food source will you test?
5. Develop a data table for collecting data.

Make sure your teacher has approved your experimental plan before you proceed further.

Data and Observations

1. Carry out your experiment. Make your measurements, and complete your data table.
2. Make a line graph that illustrates your results.

Data Analysis and Interpretation

1. Was your **hypothesis** supported by your data? Explain.
2. Did other groups arrive at the same conclusions you did? Why or why not?
3. Was there a clear difference in the growth of the fungus under different conditions?
4. Do you think different fungi would require different conditions for growth? Why or why not?
5. Explain your graph in a brief paragraph.
6. Draw and label a bit of fungus using the high power of a microscope. Be sure to include labels for each part of the fungus you can identify. Your drawing should be large, colored with map pencils, and include the magnification from which you made the drawing.
7. Write a brief conclusion to your experiment based on your data.

Going Further

Based on your data and observations, design another experiment that would help to expand your conclusions or answer questions that came up in your mind as you conducted your experiment.

CHAPTER REVIEW

SUMMARY

9-1: Kingdom Protista

1. Protists are eukaryotic organisms. They can be one- or many-celled but do not have the complex organization found in plants and animals.

2. The Protist Kingdom is made up of a variety of organisms. Some are plantlike, others are animal-like, and others are funguslike.

3. Algae are photosynthetic and classified according to their pigments. Other protists, like flagellates and ciliates, are animal-like and have special means of locomotion. Funguslike protists include slime molds and water molds.

9-2: Kingdom Fungi

1. Fungi are saprophytes. They reproduce by spores. The structures in which a fungus produces spores are used to classify fungi into one of four divisions.

2. Zygote fungi produce spores in small round spore cases on the tips of upright hyphae. Bread mold is a zygote fungus. Sac fungi produce spores in small sacs called asci. Yeast is an example of a sac fungus. Mushrooms are club fungi. Club fungi produce spores in a club-shaped structure called a basidium. These structures line the gills of a mushroom cap.

3. Imperfect fungi are those for which no sexual stage has been observed. Penicillin is an important product of these fungi.

9-3: Science and Society: Fungus—Can't Live Without It

1. Fungi are important sources of drugs such as penicillin, streptomycin, vidarabine, and cyclosporine.

2. Medicines produced from fungus products have saved the lives of millions of people with diseases such as pneumonia and tuberculosis, as well as those who have had organ transplants.

KEY SCIENCE WORDS

a. **algae**
b. **asci**
c. **basidium**
d. **budding**
e. **chitin**
f. **cilia**
g. **hyphae**
h. **lichen**
i. **mutualistic**
j. **protists**
k. **protozoa**
l. **pseudopods**
m. **sporangia**
n. **spores**
o. **symbiosis**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. footlike cytoplasmic extensions
2. reproductive cells of fungi
3. eukaryotic organisms that are animal-like, plantlike, or funguslike
4. animal-like protists
5. plantlike protists
6. threadlike structures used for movement
7. a close relationship between two organisms
8. threadlike strings of a fungus
9. contain spores in zygote fungi
10. strong carbohydrate in fungus' cell walls

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. ______ (is) are examples of one-celled algae.
   a. Paramecia c. Amoebas
   b. *Plasmodium* d. Dinoflagellates
2. Members of phylum Chrysophyta are ______ in color.
   a. green c. golden-brown
   b. red d. brown
3. Large numbers of ______ cause red tides.
   a. *Euglena* c. *Ulva*
   b. diatoms d. dinoflagellates
4. Brown algae belong to phylum ______.
   a. Rhodophyta c. Phaeophyta
   b. Chrysophyta d. Pyrrophyta
5. ______ moves by using cilia.
   a. *Amoeba* c. *Plasmodium*
   b. *Paramecium* d. *Euglena*
6. Funguslike protists can live well ______.
   a. on decaying logs c. on dry surfaces
   b. in bright light d. on metal surfaces
7. Decomposition is an important role of ______.
   a. protozoans c. plants
   b. algae d. fungi
8. All mutualistic relationships ______.
   a. are harmful c. form lichens
   b. are helpful d. pollute
9. ______ produce the spores in mushrooms.
   a. Sporangia c. Asci
   b. Basidia d. Hyphae
10. An example of an imperfect fungi is ______.
    a. mushroom c. *Penicillium*
    b. yeast d. lichen

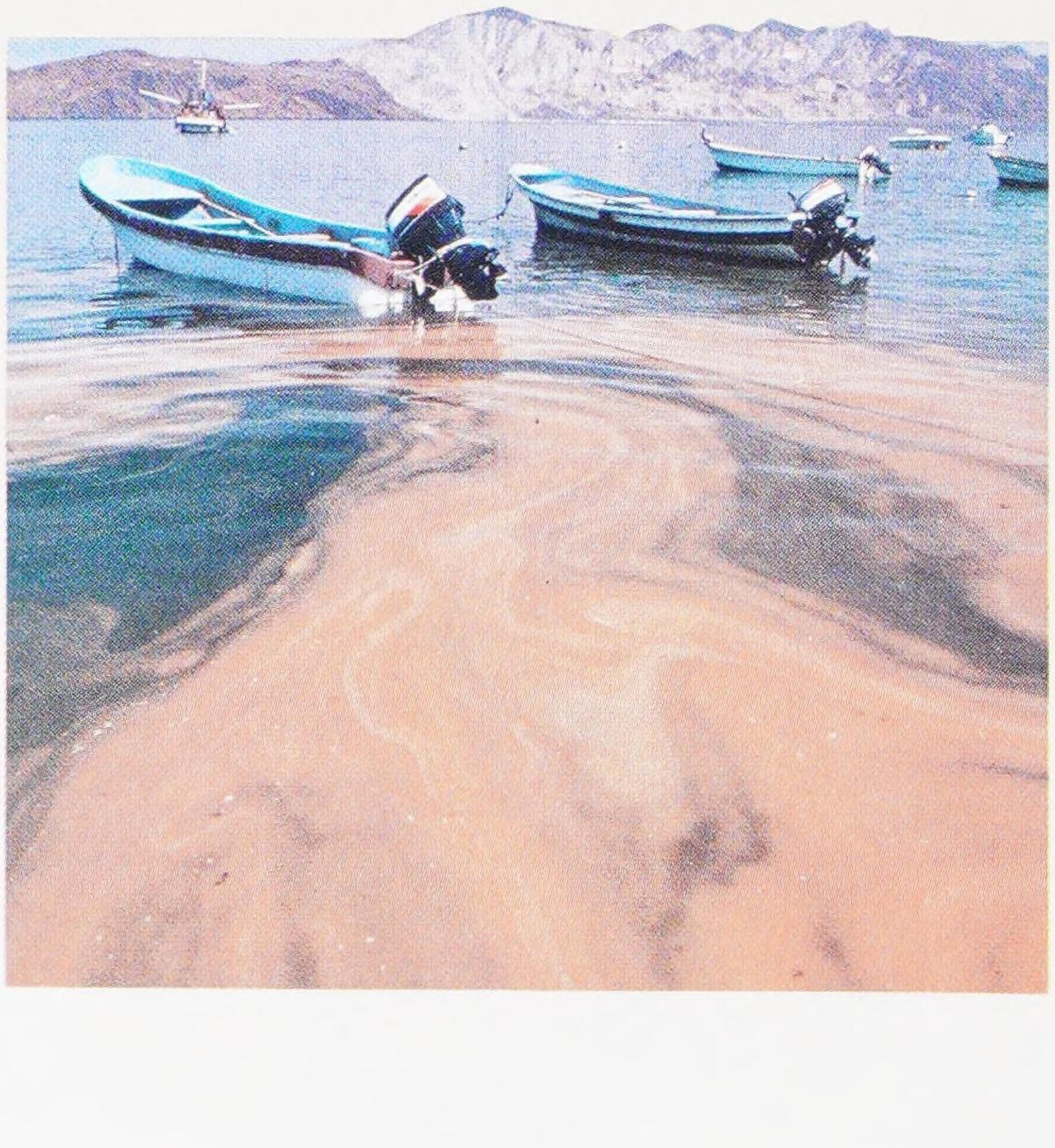
USING LAB SKILLS

11. **In your Journal,** make a hypothesis and design an experiment to test what fruits allow *Penicillium* mold to grow. Conduct your experiment. Collect data and state a conclusion.
12. In the MINI-Lab on page 214, you made a spore print of the gills of a mushroom cap. Now carefully tease apart the top of the cap and make a wet mount slide of an *extremely* small piece. Do the same with the stalk. **In your Journal**, draw and describe what you see, and compare the two.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Explain why algae are plantlike.
14. How are fungi important to the environment?
15. How are protozoans like animals?
16. What are the causes and effects of a red tide like the one shown below?



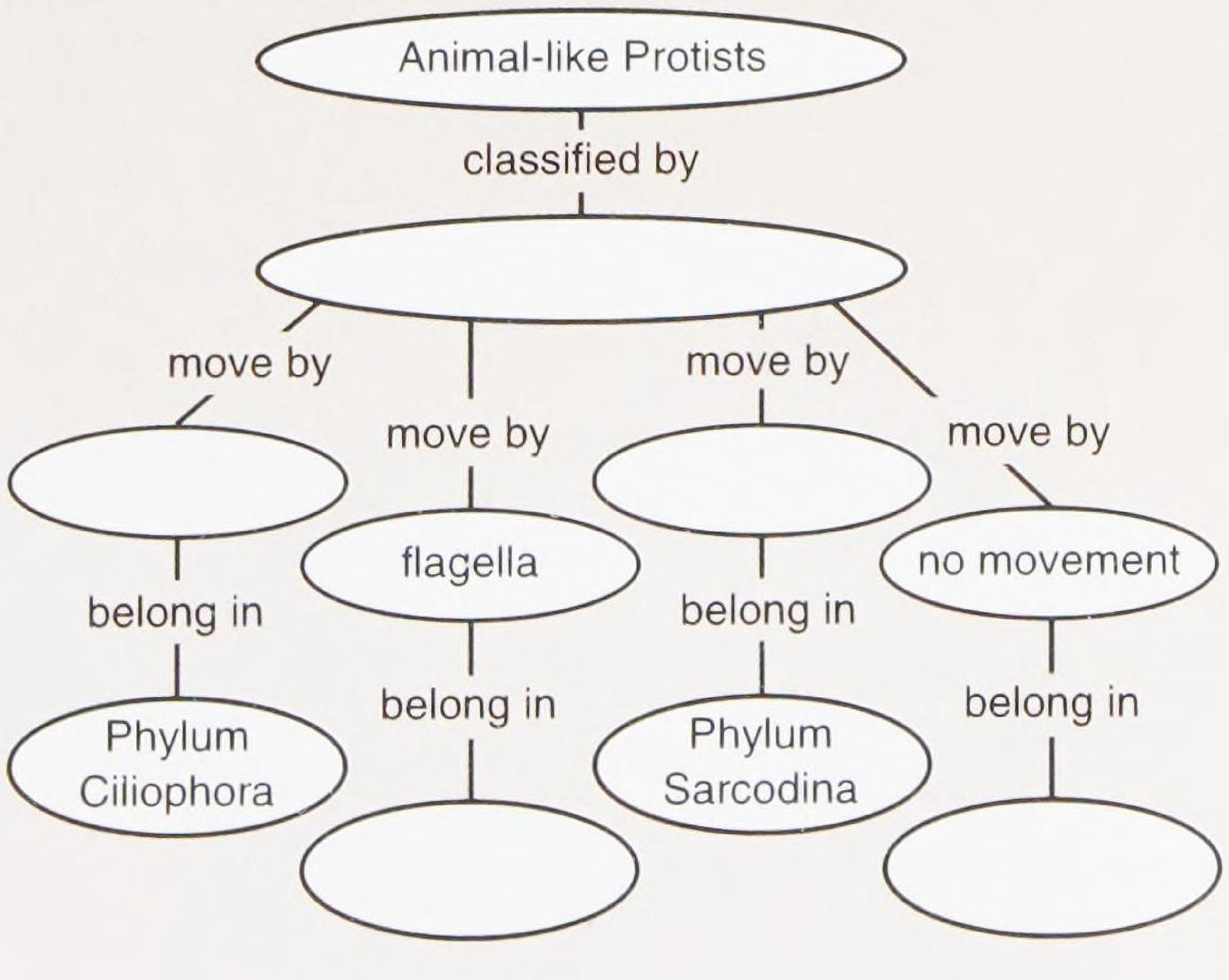
APPLY

17. Look at Figure 9-5b again. Why is *Spirogyra* a good name for this green algae?
18. Compare and contrast one-celled, colonial, chain, and many-celled algae.
19. Discuss why scientists find it difficult to trace the origin of fungi. Why are fossils of fungi rare?
20. Explain the adaptations of fungi that enable them to get food.
21. What kind of environment is needed to prevent fungal growth?

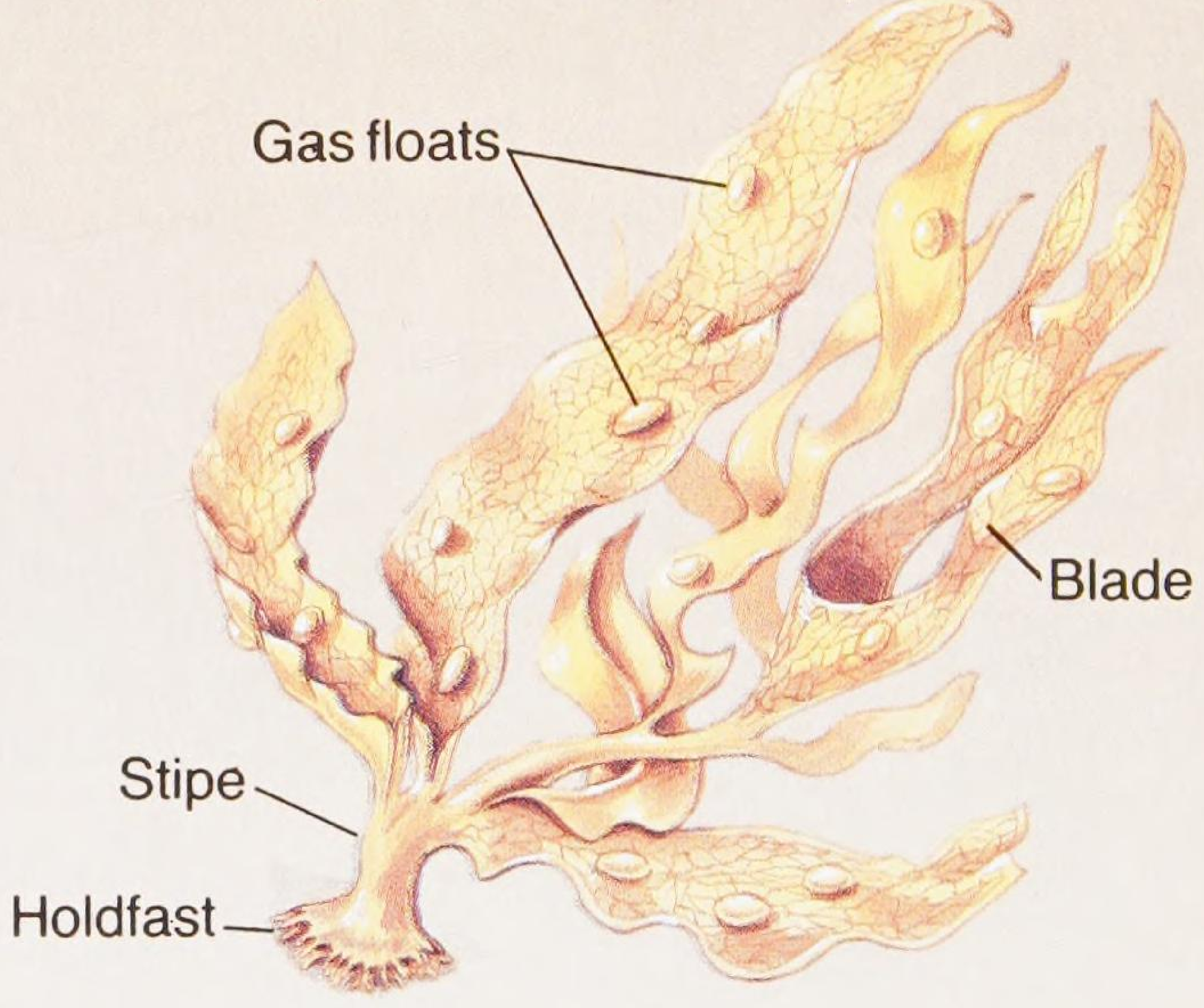
MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Observing and Inferring:** Match the prefix of each alga: *Chloro-, Chryso-, Phaeo-, Pyrro-, Rhodo,* with the correct color: brown, green, fire, gold, red.
2. **Concept Mapping:** Complete the following concept map on a separate sheet of paper.


Animal-like Protists
classified by
move by
move by
move by
move by
flagella
no movement
belong in
belong in
belong in
belong in
Phylum Ciliophora
Phylum Sarcodina

3. **Comparing and Contrasting:** Make a chart comparing and contrasting sac fungi, zygote fungi, and club fungi.
4. **Classifying:** Classify the organisms based on their method of movement. *Euglena, Amoeba,* dinoflagellates, *Paramecium, Plasmodium,* slime molds, *Trypanosoma, Volvox.*
5. **Observing and Inferring:** The figure below shows some of the structures and specialized adaptations of kelp, including the stipe, blade, holdfast, and gas floats. What purposes do these adaptations serve for kelp?


Gas floats
Blade
Stipe
Holdfast

PROJECTS

1. Bring in labels of foods that contain carrageenans. Find out what protist these are from.
2. Use samples from an aquarium, trees, and any rocks with a slick green growth from a damp area near school. Make wet mount slides and draw and label any algal growths that you find. Indentify the parts of each that take part in producing food.

UNIT 3

GLOBAL CONNECTIONS

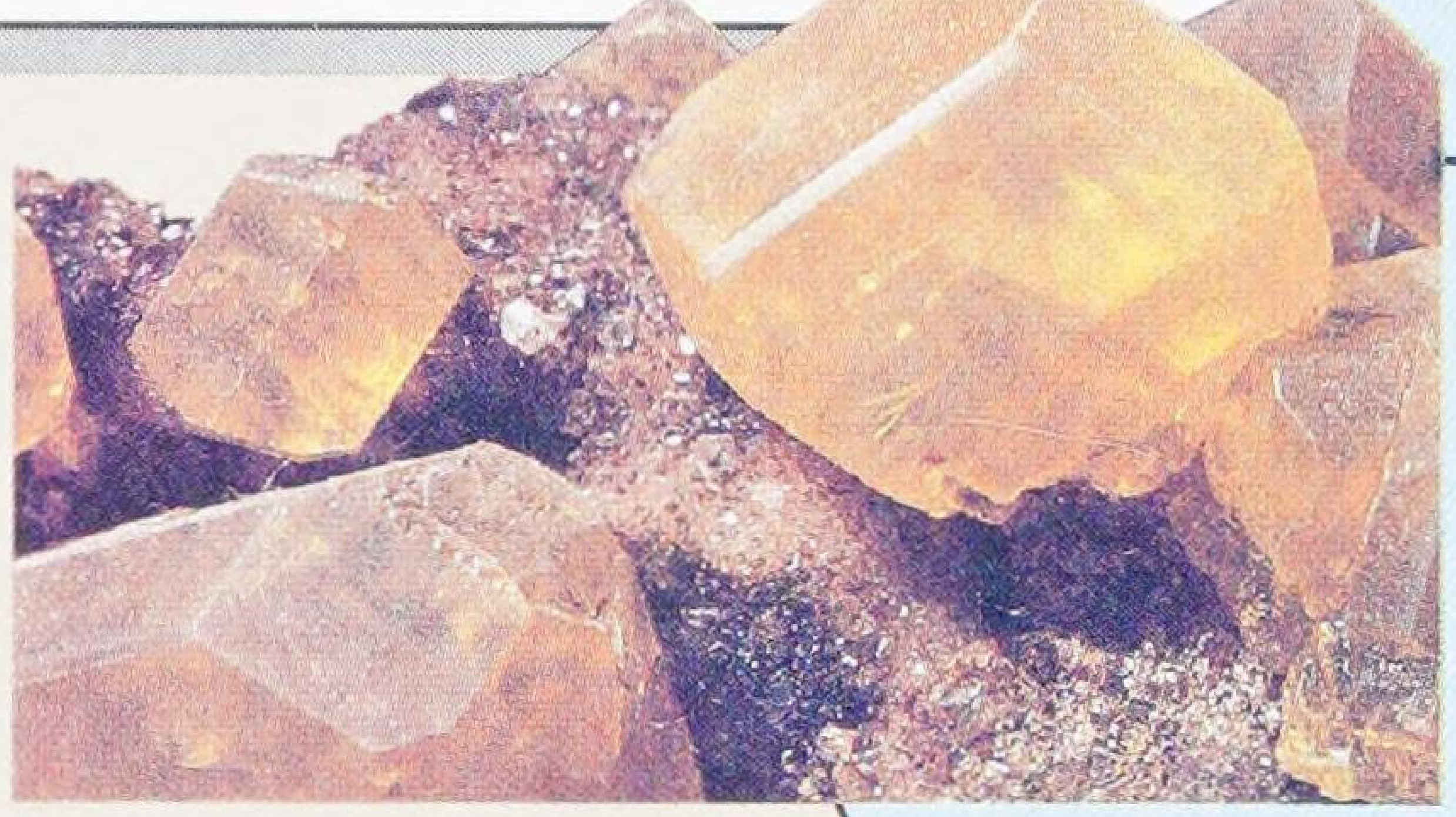
The Simplest Living Things

In this unit, you have studied viruses and simple organisms. Now find out the effects of viruses, bacteria, protists, and fungi around the world.

GEOLOGY

SULFUR BACTERIA
Sulphur, Louisiana

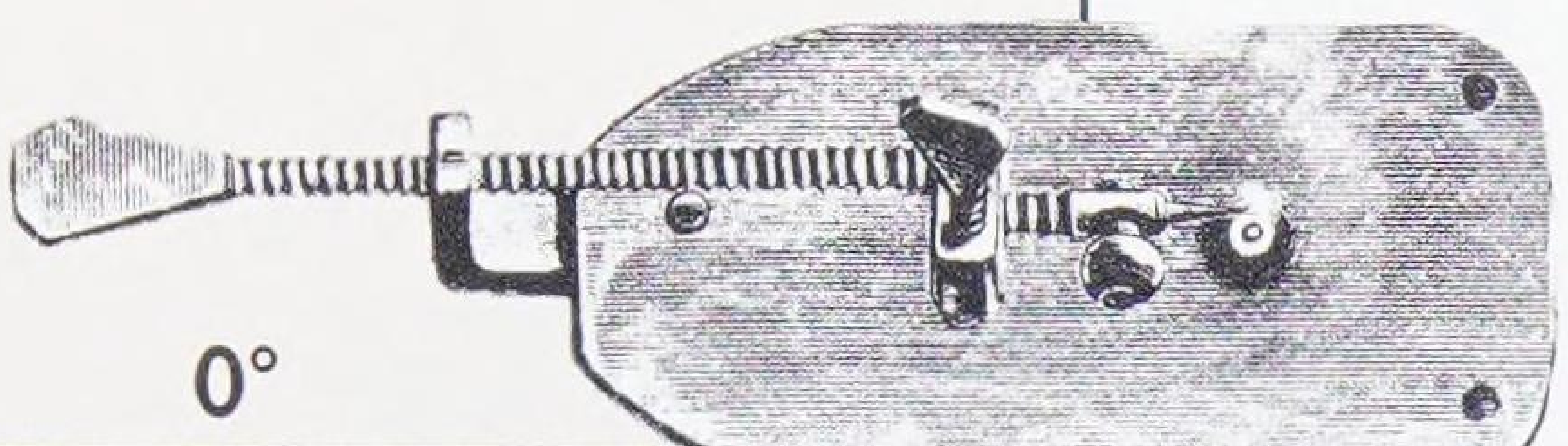
Bacteria play an important role in producing sulfur. Bacterial sulfur has been found in rocks that are 800 million years old. What can you tell about bacteria as an early life form?

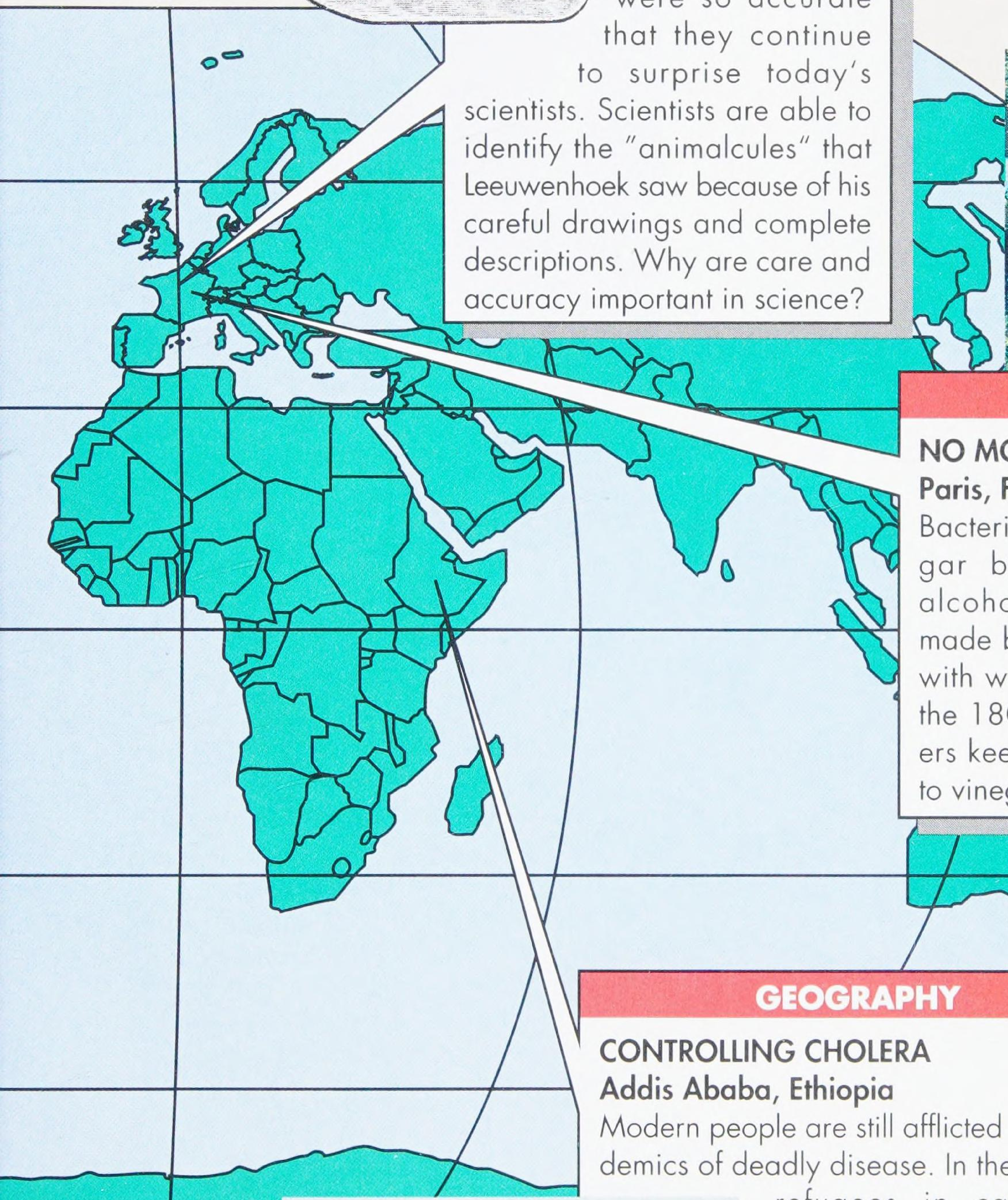


HEALTH

VICTORY OVER DISEASE
Canal Zone, Panama

Building the Panama Canal almost failed because of a tiny protist that caused malaria and a virus that caused yellow fever. Both the virus and the protist are carried by mosquitoes. How could these diseases be controlled?



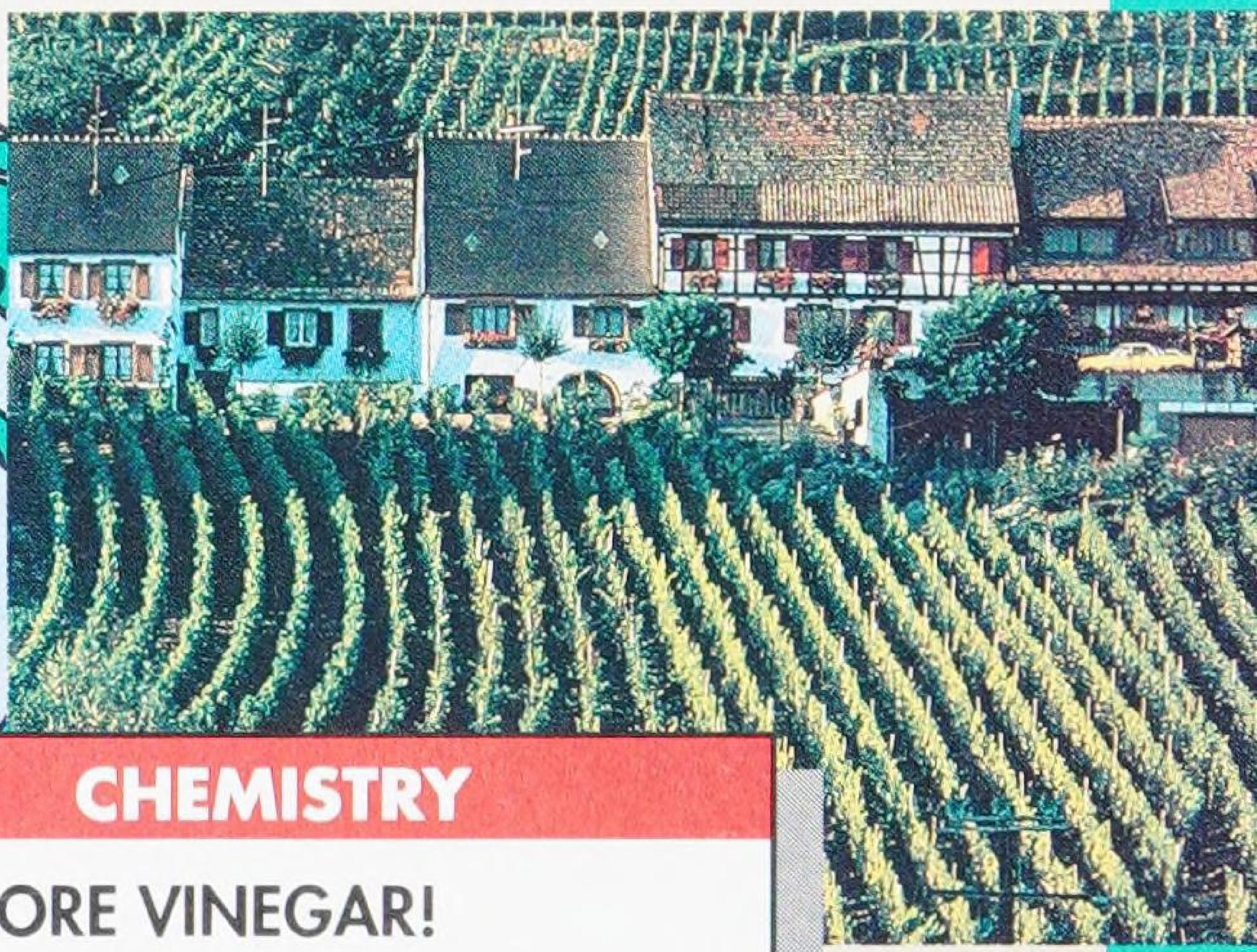


HISTORY

LIFE UNDER GLASS

Delft, Holland

Leeuwenhoek invented his microscope in the 1600s. His amazing lenses were so accurate that they continue to surprise today's scientists. Scientists are able to identify the "animalcules" that Leeuwenhoek saw because of his careful drawings and complete descriptions. Why are care and accuracy important in science?



CHEMISTRY

NO MORE VINEGAR!

Paris, France

Bacteria can turn wine to vinegar by adding oxygen to alcohol. This discovery was made by Louis Pasteur working with wine makers in France in the 1800s. How do wine makers keep the wine from turning to vinegar?

GEOGRAPHY

CONTROLLING CHOLERA

Addis Ababa, Ethiopia

Modern people are still afflicted with epidemics of deadly disease. In the 1980s, refugees in camps in Ethiopia suffered from an outbreak of cholera. How can cholera be prevented? Where else is cholera found? What United States President died from cholera while in office?

CAREERS

EPIDEMIOLOGIST

An *epidemiologist* studies the causes and spread of infectious diseases that affect large numbers of people. He or she may work in a laboratory, or at the site of an outbreak of a disease. A student interested in becoming an epidemiologist should study biology and chemistry in high school.

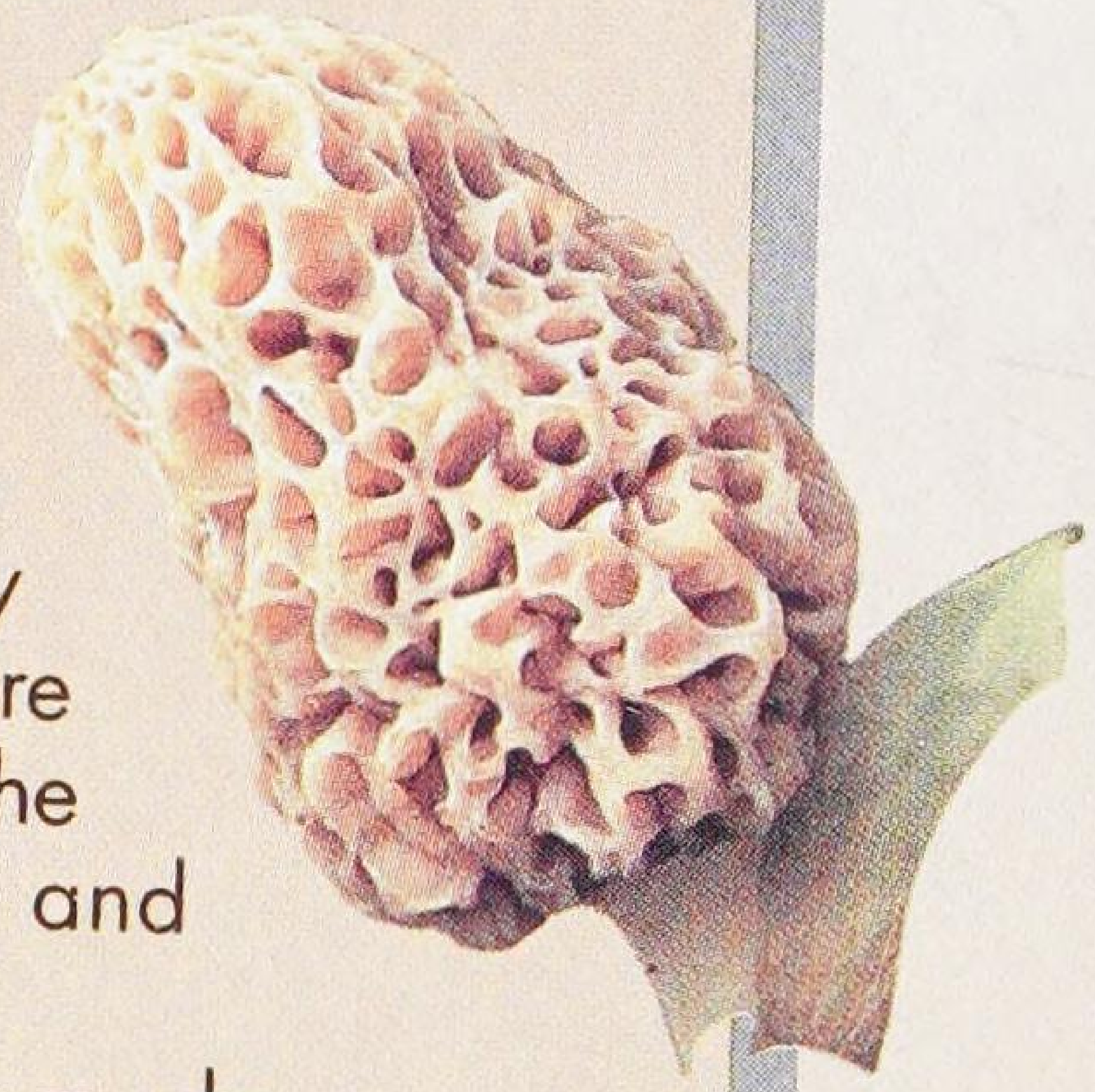
An epidemiologist will need four years of college plus graduate work in the fields of microbiology, biochemistry, physiology, and biotechnology. Many epidemiologists are medical doctors or people with doctorates who work in pathology laboratories. They may work in a national disease control center or in a university laboratory.

For Additional Information

Contact the American Society for Microbiology, Office of Education and Professional Recognition, 1913 I Street, Washington, DC 20006.

MUSHROOM FARMER

A *mushroom farmer* must have a knowledge of soils, as well as the growing conditions that mushrooms require. He or she will also need a knowledge of the varieties of mushrooms. Many new varieties of mushrooms are being cultivated because of the increase in ethnic cooking and specialty restaurants.



Most of the training a mushroom farmer needs can be learned on-the-job. To advance, these farmers should have some training in small business management. Such training can be obtained at trade schools or through community college programs. Usually, small business training programs take two years.

For Additional Information

Contact the American Farm Bureau Federation, 225 Touhy Ave., Park Ridge, IL 60068.

UNIT READINGS

- Lee, Douglas. "Slime Mold: The Fungus That Walks." *National Geographic,* July 1981.
- de Kruif, Paul. *Microbe Hunters.* Orlando, FL: Harcourt, Brace, 1926. This classic details the lives of pioneers in microbiology and their search for the cause of disease.

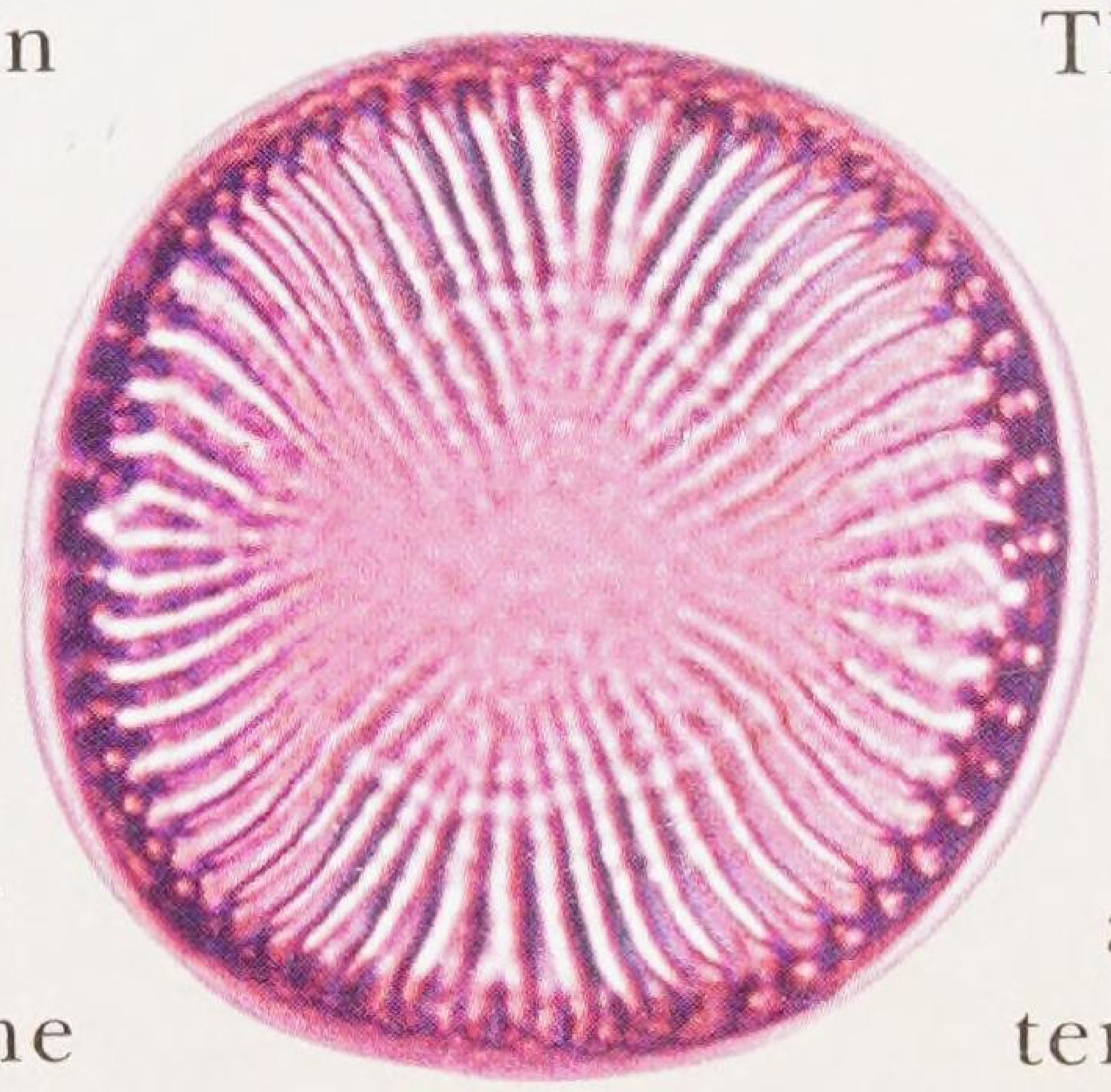
SCIENCE & LITERATURE

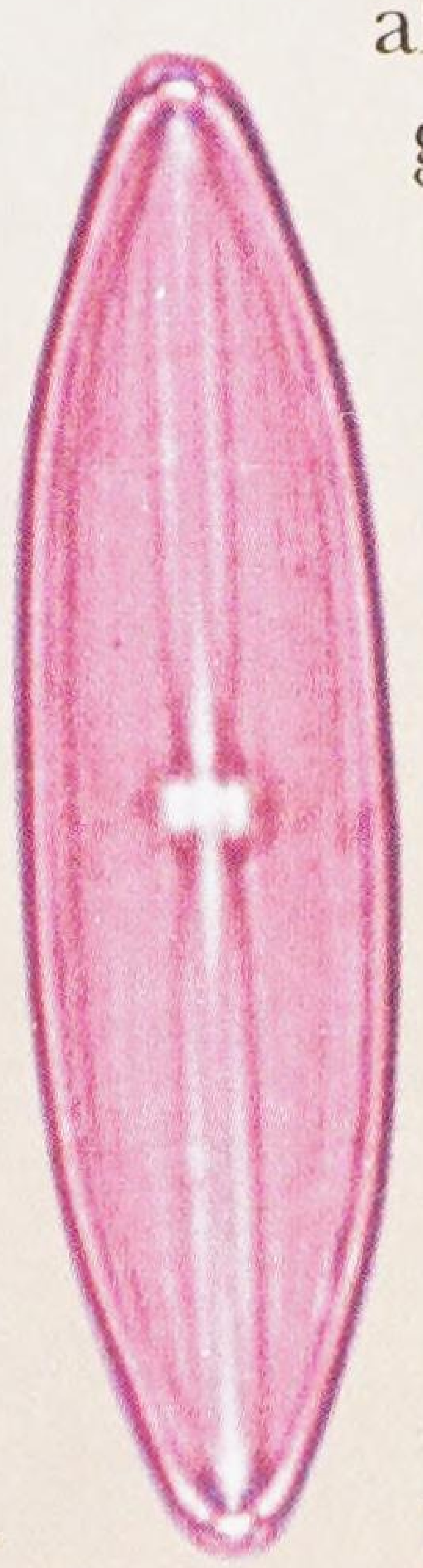
The Sea Around Us

by Rachel Carson

The following passage is taken from a chapter titled The Changing Year, which describes life in the sea as the seasons change.

In the sea, as on land, spring is a time for renewal of life. During the long months of winter in the temperate zones the surface waters have been absorbing cold. Now the heavy water begins to sink, slipping down and displacing the warmer layers below. Rich stores of minerals have been accumulating on the floor of the continental shelf—some freighted down by the rivers from the lands; some derived from sea creatures that have died and whose remains have drifted down to the bottom; some from the shells that once encased a diatom, the streaming protoplasm of a radiolarian, or the transparent tissues of a pteropod. Nothing is wasted in the sea; every particle of material is used over and over again, first by one creature, then by another. And when in spring the waters are deeply stirred, the warm bottom water brings to the surface a rich supply of minerals ready for use by new forms of life.





Just as land plants depend on minerals in the soil for their growth, every marine plant, even the smallest, is dependent upon the nutrient salts or minerals in the sea water. Diatoms must have silica, the element of which their fragile cells are fashioned. For these and all other microplants, phosphorus is an indispensable mineral. Some of these elements are in short supply and in winter may be reduced below the minimum necessary for growth. The diatom population must tide itself over this season as best it can. It faces a stark problem of survival, with no opportunity to increase, a problem of keeping alive the spark of life by forming tough protective spores against the stringency of winter, a matter of existing in a dormant state in which no demands shall be made on an environment that already withholds all but the most meager necessities of life. So the diatoms holds their place in the winter sea, like seeds of wheat in a field under snow and ice, the seeds from which the spring growth will come.

In Your Own Words

▶ Many of the simplest living things survive unfavorable living conditions as spores. Describe how this allows these life forms to survive. Write a brief essay describing the characteristics of spores. Tell what problems in the environment may cause an organism to form a spore. Also tell what must happen for the spore to resume normal growth and development.

UNIT 4 PLANTS

What's Happening Here?

How do you collect specimens 150 meters in the air? In 1989, a daring group of French scientists cleverly solved this problem by lowering a raft onto the trees of the rain forest from the air. The scientists tethered themselves to the raft for safety and then worked, ate, and slept in their unique, elevated research lab. What did they hope to learn? As rain forests are destroyed at an increasing rate, there is less time to learn about their treasures. The raft helped the scientists to find out if the plants and animals that live on the floor of the forest are different from those at home in the upper story.

UNIT CONTENTS

Chapter 10 Introduction to Plants
Chapter 11 The Seed Plants
Chapter 12 Plant Processes

CHAPTER

10 Introduction to Plants

Do you eat salads? A salad can be made up of almost anything you can think of. What plants would you choose for a salad? Do you know what plant parts you would be eating?

FIND OUT!

Do this simple activity to find out what plant parts you eat.

Make a list of five things that you might find in a garden salad. *Compare* your list with a classmate's list. Did you choose different things? Now *decide* what part of the plant each salad item is. Did you choose carrots? Carrots are roots. If you chose lettuce, you would be eating leaves. What about some sprigs of parsley? They are stems. Bean sprouts, pineapple fruit, and sunflower seeds are other parts of plants you might find in a salad.

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 10-1 Characteristics of Plants
- What Is a Plant?
- Origin and Evolution of Plants
- Adapting to Land
- Classification of Plants

Section 10-2 Seedless Plants
- Seedless Nonvascular Plants
- Seedless Vascular Plants

Section 10-3 Science and Society
Peat Moss as Fuel
- What's In a Bog?

Previewing Science Skills

- In the **Skill Builders,** you will hypothesize and make a concept map.
- In the **Activities,** you will compare, observe, and collect data.
- In the **MINI-Labs,** you will experiment, observe, measure, and calculate.

What's next?

So far, you have identified some plant parts that are common food sources. In this chapter you will learn more about the characteristics of plants and how plants are adapted to life on land.

10-1 Characteristics of Plants

New Science Words

cellulose
cuticle
vascular plants
nonvascular plants

Objectives

- ▶ List the characteristics of plants.
- ▶ Describe adaptations of plants that made it possible for them to survive on land.
- ▶ Compare vascular and nonvascular plants.

What Is a Plant?

Have you ever walked in a park? Maybe you've taken off your shoes and wriggled your toes in the cool grass. Perhaps you climbed a tree and looked at the sky through green leaves. Or you may have walked down a nature trail like the one shown in Figure 10-1 to a low, damp place where ferns grew. Grass, trees, and ferns all are members of the Plant Kingdom.

Now look at Figure 10-2. These organisms, mosses and liverworts, have characteristics that identify them as plants, too. What do they have in common with grass, trees, and ferns? What makes a plant a plant?

All plants are many celled and most contain the green pigment chlorophyll. Cell walls surround plant cells and give them structure. Most plants have roots or rootlike

Figure 10-1. All plants are many-celled and most contain chlorophyll. Grass, trees, and ferns all are members of the Plant Kingdom.

structures that hold them in the ground, so plants usually do not move around. Plants are eukaryotes that have adapted successfully to life on land. In fact, they have adapted so well that they are found in nearly every environment on Earth. From the frigid, ice-bound Antarctica to the hot, dry deserts of Africa, plants have evolved to survive even the most extreme conditions.

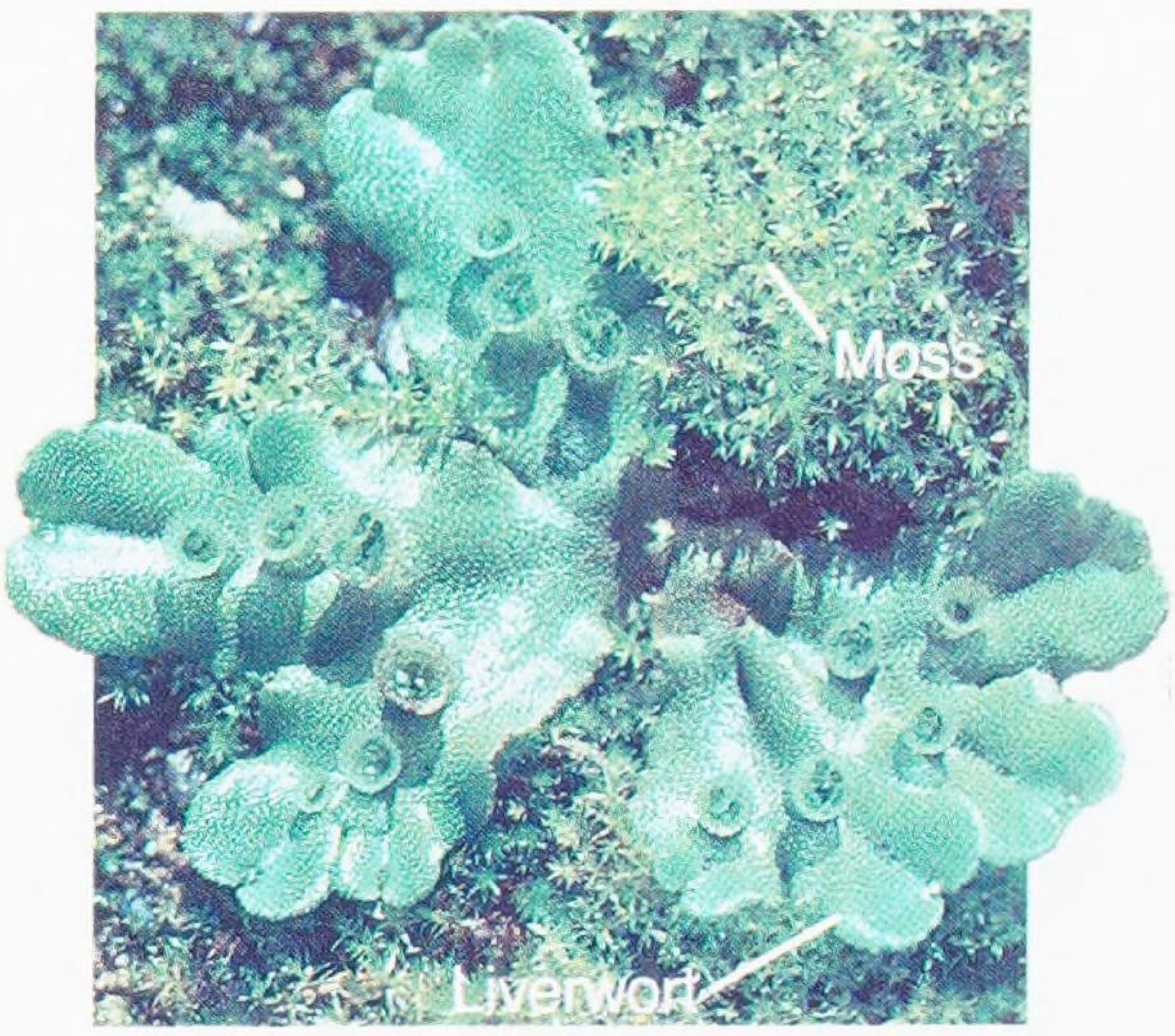


Figure 10-2. Simple plants include mosses and liverworts like these.

Most plants live on land, but many live in or near water. Plants range in size from tiny water ferns that are so small they require a hand lens to see, to the giant sequoia trees of the western United States, some of which are over a thousand years old and 100 m in height.

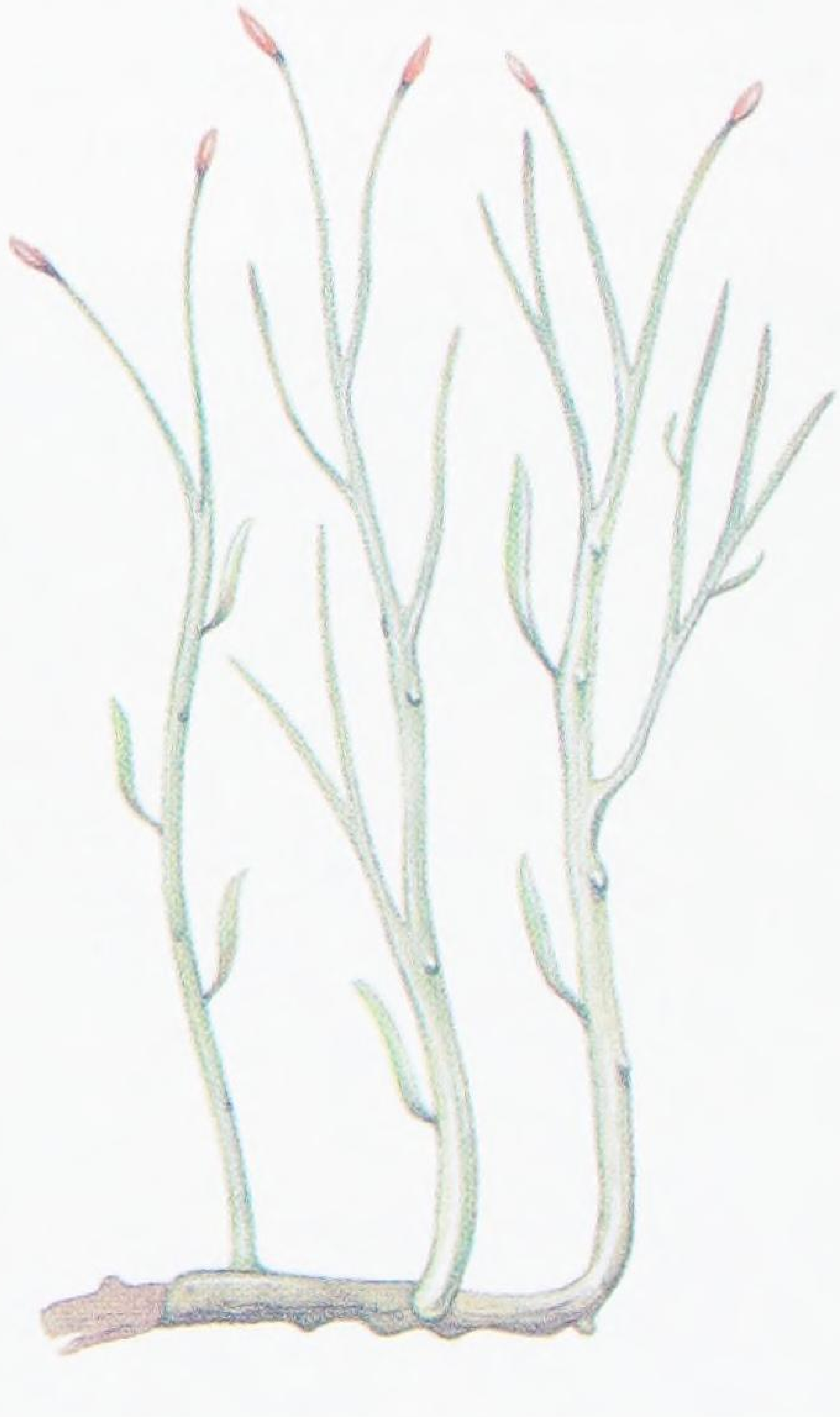
About 285,000 plant species have been identified, and scientists think there are many more still to be found, mainly in tropical rain forests. If you were asked to make a list of all the plants you could name, you probably would name vegetables, fruits, and field crops like wheat, rice, or corn. These plants are important food sources to humans and other consumers. Without green plants, life on Earth as we know it would not be possible.

Why are green plants important to consumers?

Origin and Evolution of Plants

Where did the first plants come from? Like all life, early plants probably came from the sea, evolving from plantlike protists. What evidence is there that this occurred? Both plants and green algae have the same types of chlorophyll as well as carotenoids (kuh RAT uh noydz) in their cells. Carotenoids are red, yellow, or orange pigments found in chloroplasts and in all cyanobacteria. Carrots are orange in color because of these pigments.

Figure 10-3. *Rhynia major* is one of the earliest land plants known.



One way of understanding the evolution of plants is to look at the fossil record. Unfortunately, the fossil record for plants is not as good as that for animals. Plants usually decay before they form fossils. The oldest fossil plants are from the Devonian period and are about 400 million years old. Available fossils show that early plants were very similar to the plantlike protists. Fossils of *Rhynia major* represent the earliest land plants known. This fossil plant is illustrated in Figure 10-3. These plants had no leaves, and their stems grew underground. Scientists hypothesize that these kinds of plants evolved into the simple plants of today.

Adapting to Land

Imagine life for a one-celled green alga floating in a shallow pool. The water in the pool surrounds and supports the alga cell. It can make its own food through the process of photosynthesis, and materials move freely into and out of the cell membrane by osmosis and diffusion. The alga has everything it needs to survive.

Now imagine a summer drought. The pool begins to dry up. Soon the alga lies on the damp mud. What will happen to the alga? It can still make its own food, so it won't starve. As long as the ground stays damp, the alga can move materials in and out through the cell membrane. But it is no longer supported by the pool's water. What will happen to the alga if the land continues to dry up? The alga will lose water through the cell membrane by osmosis. Remember that in osmosis, water molecules diffuse through a membrane from an area of higher concentration to one of lower concentration. Water will diffuse out of the alga to the drier pond bottom. Without water, the alga will die.

What adaptations would make it possible for plants to survive on land? What would help the plant conserve water? Loss of water is a major problem plants face. Plant cells have cell membranes like the protists do, but they also have rigid cell walls outside the membrane. Cell walls are made of **cellulose,** an organic compound made up

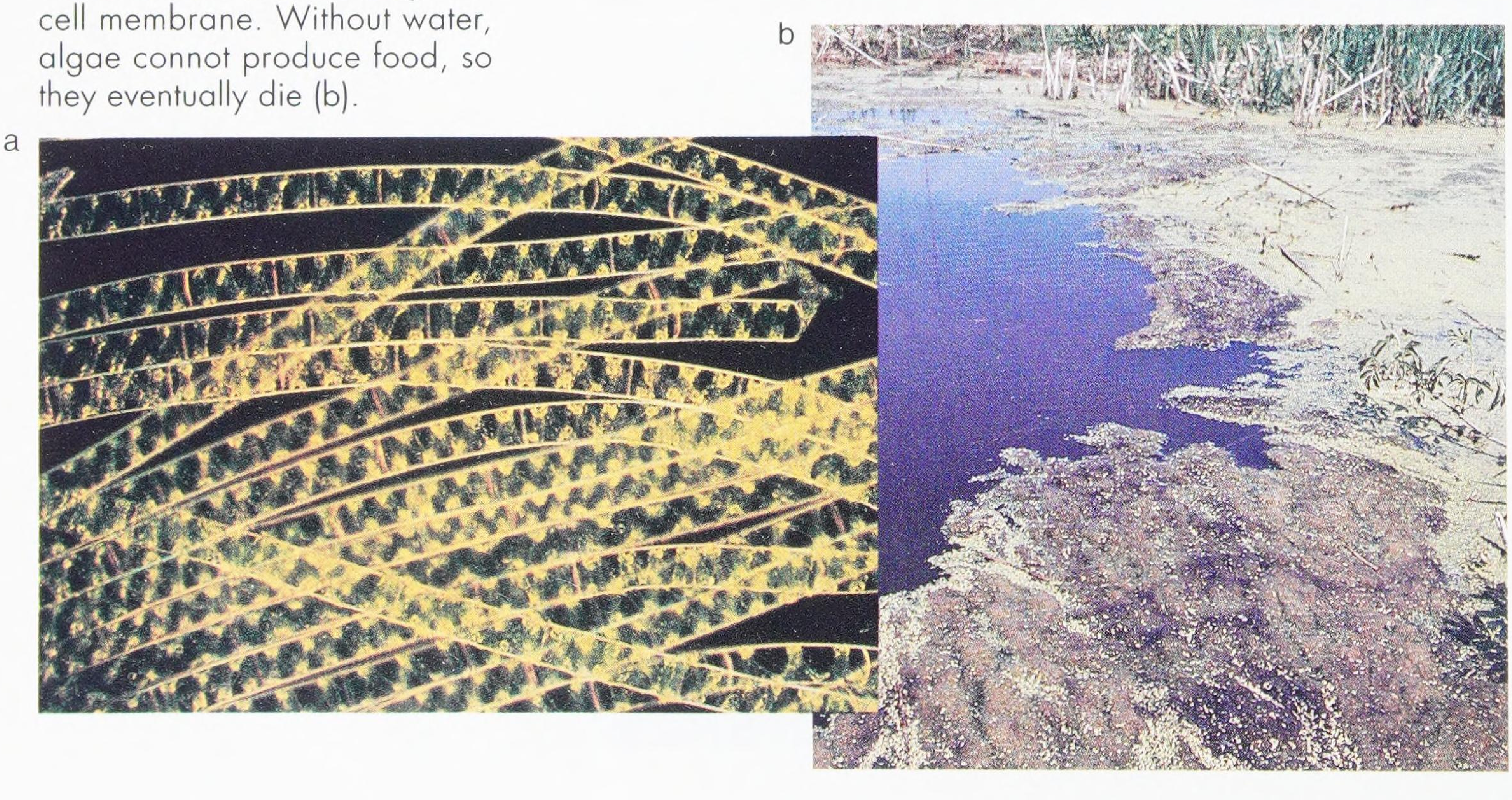


Figure 10-4. Green algae (a) produce their own food and move materials in and out through the cell membrane. Without water, algae connot produce food, so they eventually die (b).

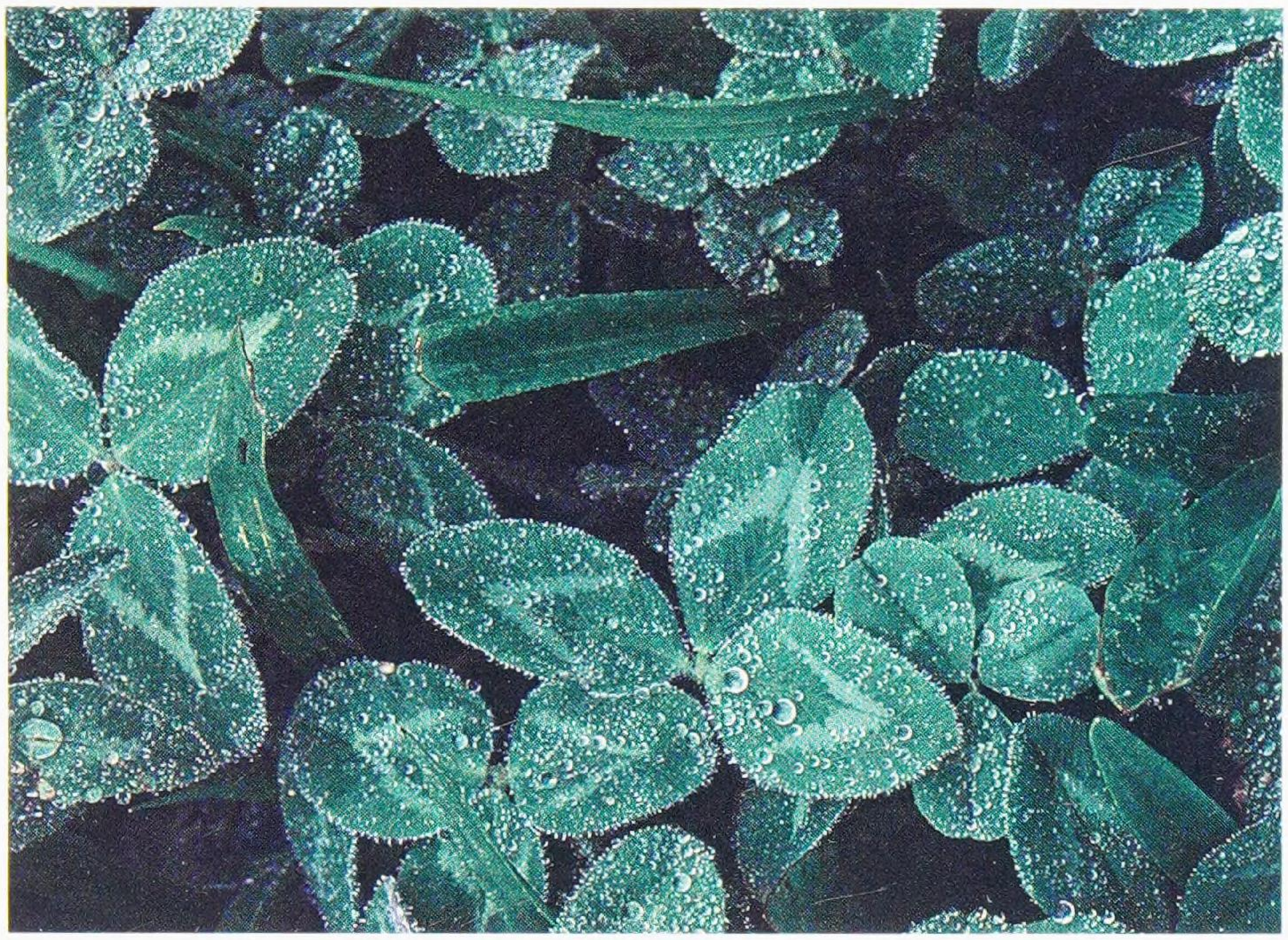


Figure 10-5. Cell walls and waxy cuticles are adaptations that enable plants to survive on land.

of long chains of sugar molecules. Wood is about 50 percent cellulose. Cell walls help prevent plant cells from drying out and provide structure and support. Most land plants also have a waxy, protective layer on stems and leaves called a **cuticle.** The next time it rains, go outside and see how raindrops bead up on the surface of most plant leaves or flower petals. The rain rolls right off because of the waxy cuticle. The cuticle is an adaptation that helped plants to keep from drying out on land.

How does a cuticle help a plant adapt to life on land?

Another problem plants faced in the move onto land was reproduction. Plants evolved from organisms that reproduced in water. As a matter of fact, these species were completely dependent on water for reproduction and survival. Simple plants still require water to reproduce. You will learn more about reproduction in simple plants in Section 10-2. More complex plants evolved ways to reproduce that do not require water. Reproduction in these plants is discussed in Chapter 11.

There are some advantages to life on land for plants. For one thing, there's a lot more sunlight available for photosynthesis on land than in water. Another advantage of life on land is the availability of carbon dioxide. There is much more carbon dioxide in the air than in the water. Carbon dioxide is a gas that plants use to produce food. All plants still need water to carry nutrients into and waste products out of their cells. They also need structures to support their weight on land. These supports eventually came in the form of stems and roots.

Connect to...

Chemistry

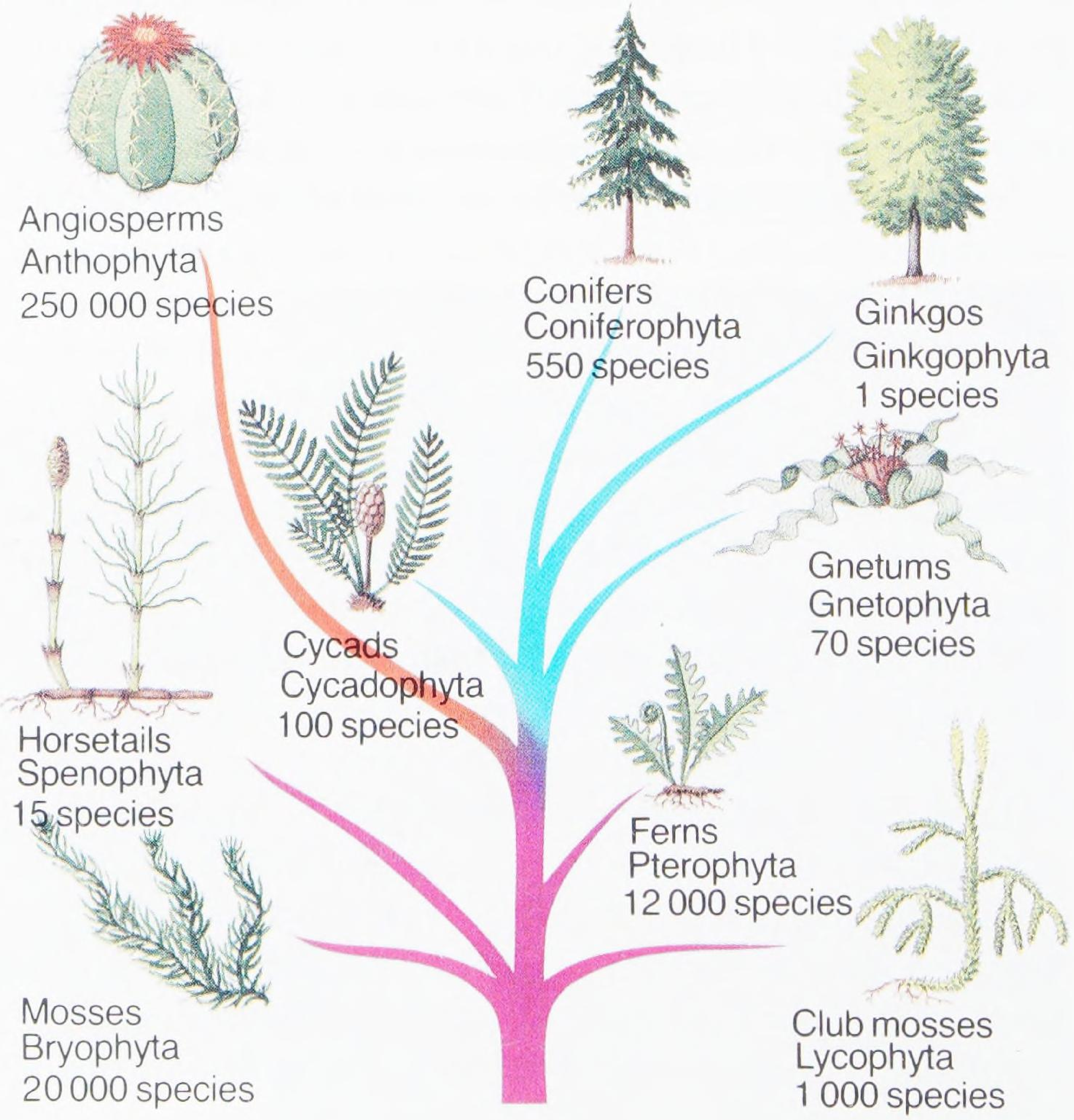
Cellulose, found in plant cell walls, is an organic compound composed of many glucose units strung together. More than half the carbon in plants is in the form of cellulose. Raw cotton is over 90 percent cellulose. Which physical property do you think makes cellulose ideal for helping plants survive on land?

Classification of Plants

Today, plants usually are classified into major groups called divisions. A division is the same level as the phylum you've studied in the Protist Kingdom. The simplest plants—mosses and liverworts—are placed in the division Bryophyta (bri uh FITE uh).

What are plants with and without vessels called?

Bryophytes are small plants found in damp environments like the forest floor, the edges of ponds and streams, and near the ocean. Bryophytes are usually just a few cells thick, so they are able to absorb water directly through their cell walls. Plants in the more complex divisions of the Plant Kingdom have systems in which water and nutrients are transported through the plant in tubelike vessels. In a sense, these vessels are similar to blood vessels. Vessels transport materials to all plant cells. Plants with vessels are more than a few cells thick. Plants that have vessels are **vascular plants.** Most of the plants you know, such as trees, bushes, and flowers, are vascular plants. Plants without vessels, the bryophytes, are **nonvascular plants.** Why is it an advantage for nonvascular plants to be located in damp areas?



Angiosperms
Anthophyta
250 000 species
Conifers
Coniferophyta
550 species
Ginkgos
Ginkgophyta
1 species
Gnetums
Gnetophyta
70 species
Cycads
Cycadophyta
100 species
Horsetails
Spenophyta
15 species
Ferns
Pterophyta
12 000 species
Mosses
Bryophyta
20 000 species
Club mosses
Lycophyta
1 000 species

Figure 10-6. The Plant Kingdom

TECHNOLOGY

Oil from Desert Plants

The jojoba (ho HO bah), a desert plant, produces brown, peanut-sized seeds that contain an oil very similar to sperm whale oil. Trade in sperm whale oil was banned in the United States in 1970. Sperm whale oil was used in many products, from face creams to transmission fluids. Faced with a ban on sperm whale oil, industries tried new oils, including jojoba oil.

Jojoba seeds contain 50 percent oil by weight. This oil has a very high boiling point (398°C) and is valuable for lubricating machinery. Jojoba oil has no cholesterol and can be a healthy substitute for cooking oils. Used also in soap and cosmetics, jojoba has a promising future. However, it is expensive because, until recently, most oil was extracted from seeds collected in the desert. Only a few thousand hectares have been planted commercially so far.

Think Critically: How does the availability of jojoba oil affect its usefulness to industry?

SECTION REVIEW

1. List the characteristics of plants.
2. What adaptations make life on land possible for plants? What are some advantages of life on land for plants?
3. Compare vascular and nonvascular plants.
4. **Apply:** If you left a board lying on the grass for a few days, what would happen to the grass underneath the board? Why?
5. **Connect to Chemistry:** To which class of organic compounds (proteins, carbohydrates, or lipids) does the material that makes plant cuticles belong?

Skill Builder

Hypothesizing

From what you have learned about adaptations necessary for life on land, make a **hypothesis** as to what types of adaptations land plants might have if they had to survive submerged in water. If you need help, refer to Hypothesizing in the **Skill Handbook** on page 686.

10-2 Seedless Plants

New Science Words

rhizoids
sporophyte
gametophyte
alternation of generations
pioneer species
epiphyte
rhizome
frond
sori
prothallus

Objectives

- Describe the life cycles of mosses and ferns.
- Compare simple nonvascular plants with simple vascular plants.
- State the importance of simple nonvascular and vascular plants.

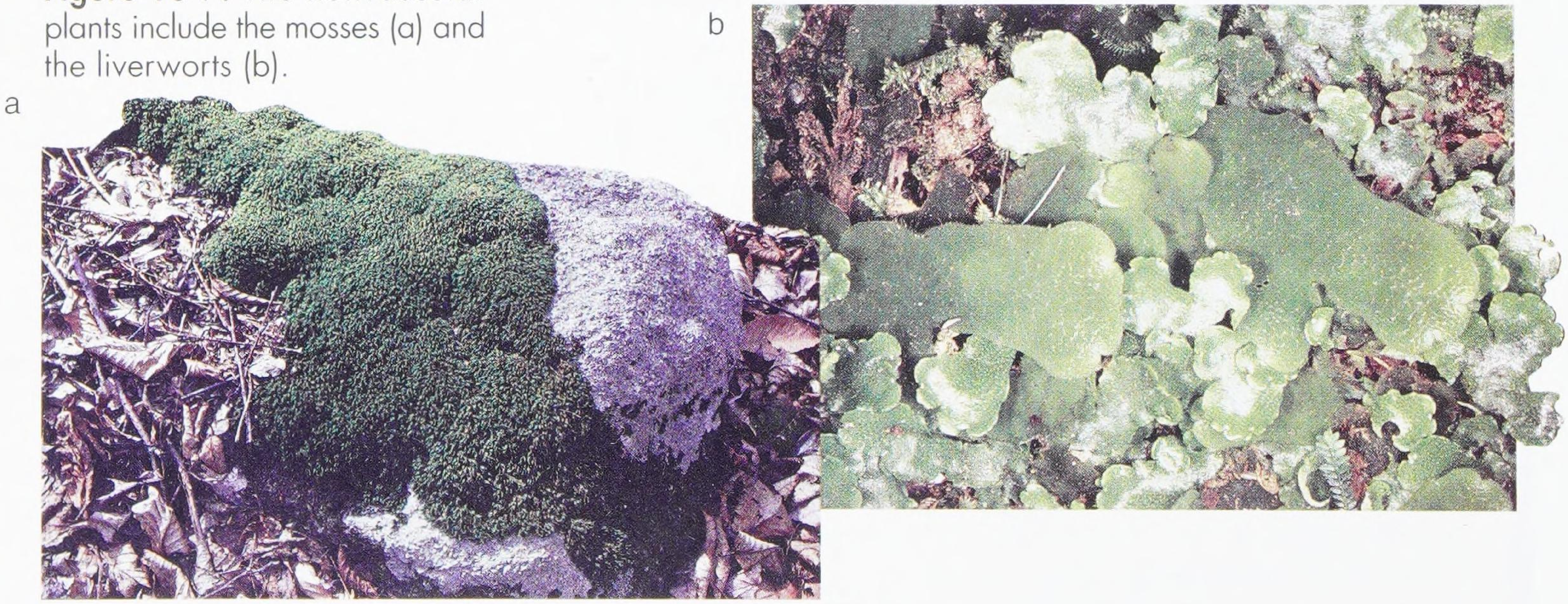
Seedless Nonvascular Plants

If you were asked to name the parts of a plant, you probably would list roots, stems, leaves, and perhaps flowers. You may also know that many plants grow from seeds. But did you know that some simple plants have none of these parts? Nonvascular plants, the bryophytes, do not have roots, stems, or leaves. They do have rootlike fibers, stalks that look like stems, and leaflike green growths. Instead of growing from seeds, bryophytes grow from spores. The nonvascular plants include the mosses and liverworts. Figure 10-7 shows some common types of nonvascular plants.

What is a moss?

A moss is a simple rootless plant with leaflike growths in a spiral around a stalk. Moss plants are held in place by rootlike filaments or threads made up of only a few long cells called **rhizoids.** A liverwort is a simple, rootless plant that has a flattened, leaflike body. Liverworts get their

Figure 10-7. The nonvascular plants include the mosses (a) and the liverworts (b).



name because, to some people, they look like a liver. In the ninth century, liverworts were thought to be useful in treating diseases of the liver. The ending, *-wort,* means "herb," so the word *liverwort* means "herb for the liver." In liverworts, each rhizoid is made up of just one cell. Both mosses and liverworts are small plants that grow in damp areas. They range in size from 2 to 20 centimeters in height.

Of approximately 20 000 species of nonvascular plants, most are classified as mosses. Have you ever seen mosses growing on tree trunks, rocks, or the ground in damp or humid areas? If conditions are right, mosses grow right on the sides of wood houses.

The Moss Life Cycle

A typical growth of moss plants looks like a soft, green carpet on the forest floor, as shown in Figure 10-7a. Now look at the closeup of the moss plants in Figure 10-8. Can you see the structures sticking up out of the leaflike plants? These are the moss sporophytes. A **sporophyte** includes a stalk and a capsule in which numerous haploid spores are produced. Eventually, the capsule breaks open and the spores are scattered. When a haploid spore lands on wet soil or rocks, it germinates into a thin, threadlike green structure. Within a few days, small gametophyte moss plants begin to grow here and there along the thread. A **gametophyte** is the form of a moss plant that produces sex cells. Sometimes a moss gametophyte produces only male or female sex cells, but often both types are produced. During a heavy dew or rain, the male sperm get splashed onto the female gametophyte. They swim to the female eggs. When the male and female sex cells unite, a diploid zygote forms. The zygote divides by mitosis to form an embryo, which in turn develops into a sporophyte, and the cycle begins again. This continual cycle that alternates between the spore-producing phase and sex

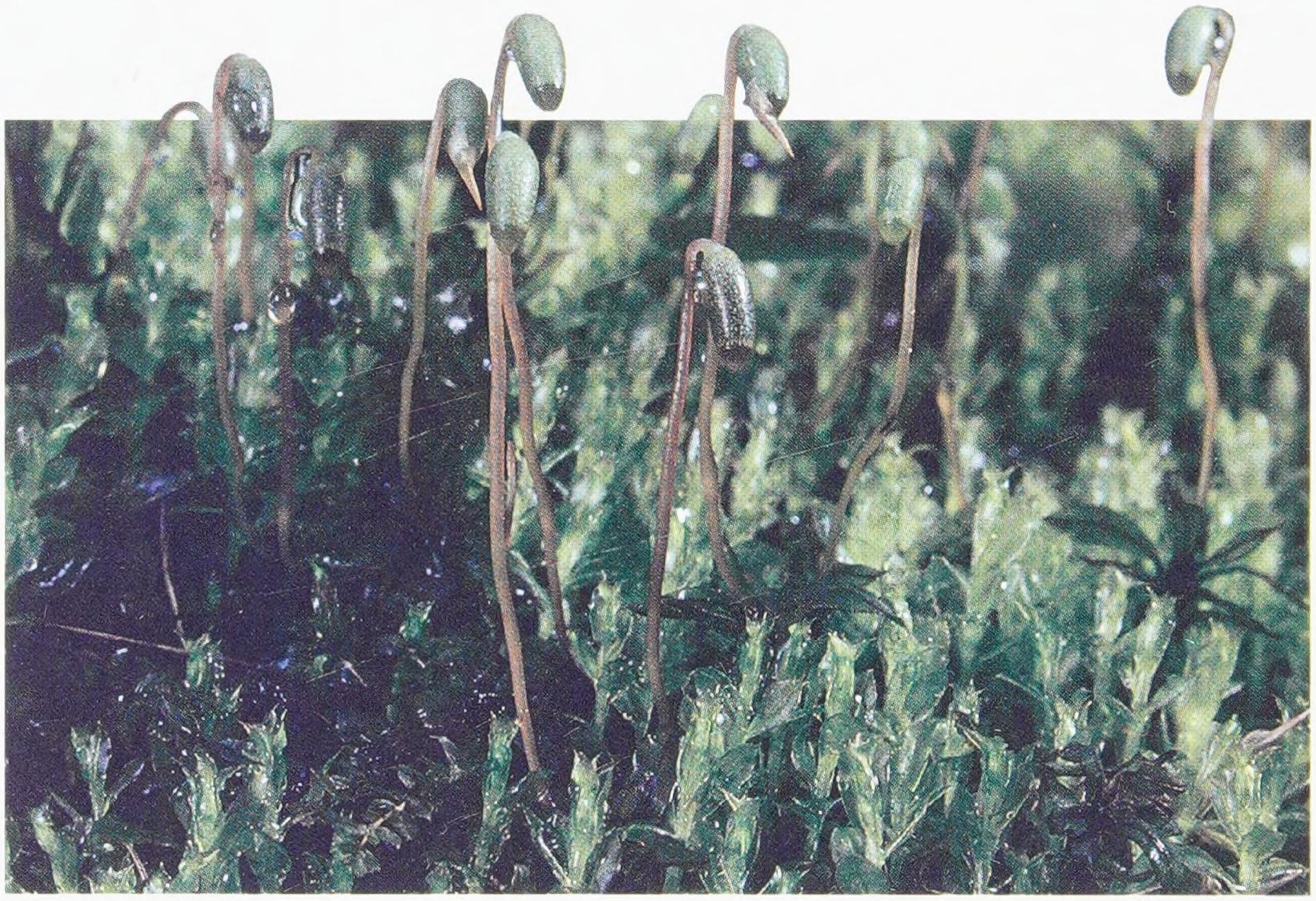


Figure 10-8. The leafy green gametophytes of moss support the stalks and capsules of the moss sporophytes.

What is a gametophyte?

What is alternation of generations?

cell-producing phase of the moss plant is called **alternation of generations** and represents sexual reproduction in mosses. In bryophytes, the most visible plant is the green, leaflike gametophyte. The life cycle of a moss, including the alternation of generations, is shown in Figure 10-9. Liverworts have a life cycle similar to that of the mosses.

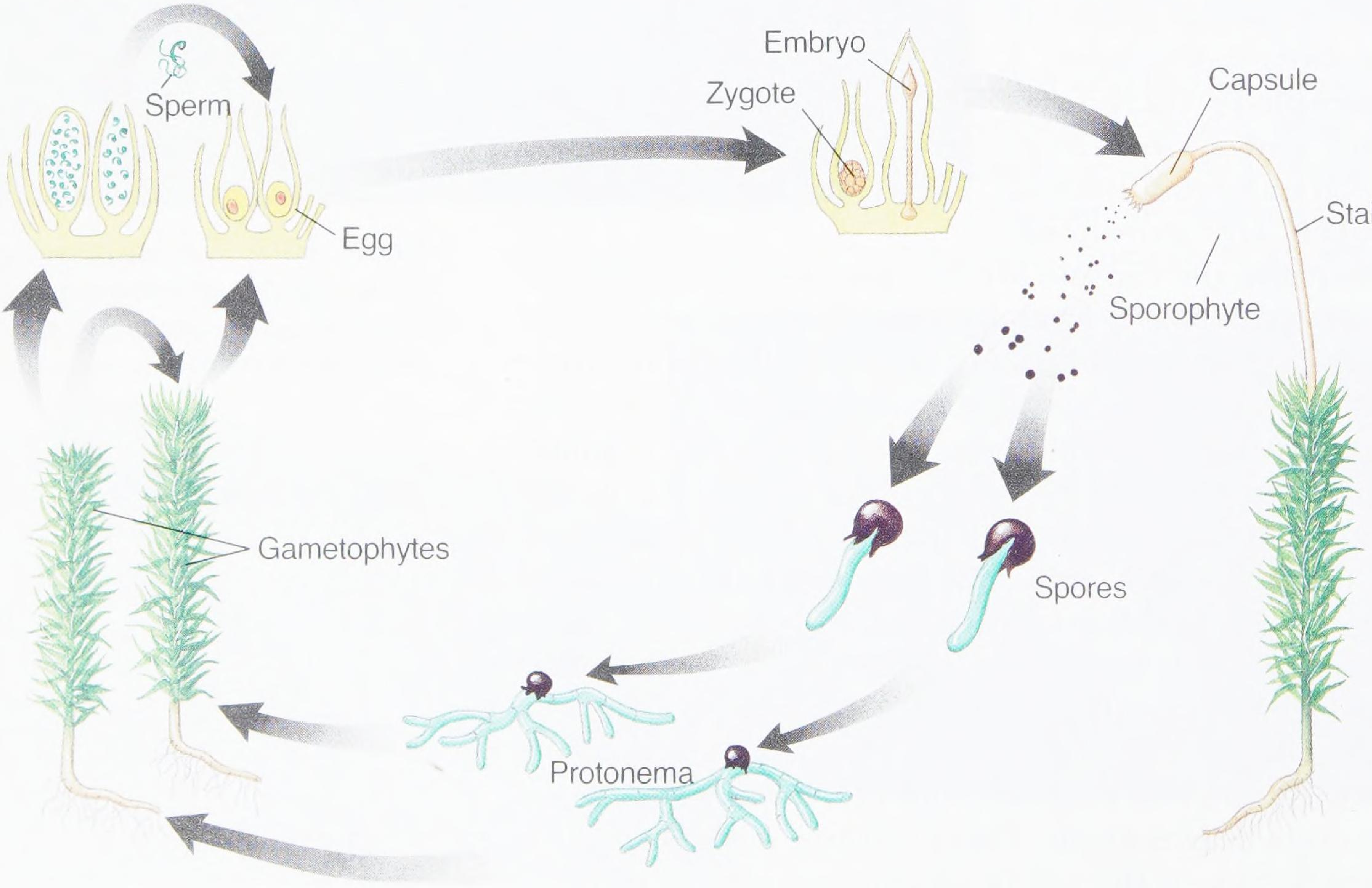
In Your JOURNAL

In your Journal, write a poem or a memory code to help you remember the life cycle of mosses.

In addition to the alternation of generations, both mosses and liverworts reproduce asexually. New moss plants can develop when a small piece of the parent plant breaks off. Liverworts develop small balls of cells within cuplike structures on the surface of the leaflike body. These balls of cells can be carried by water to new areas where they grow into new plants.

All plants have a life cycle in which the sporophyte and gametophyte alternate. In other words, all plants go through a diploid and a haploid stage in sexual reproduction. In nonvascular plants like mosses and liverworts, the sporophytes depend on the gametophytes for water and nutrients. In the more complex vascular plants, like tulips and oak trees, the sporophyte doesn't depend on the gametophyte for these things.

Figure 10-9. The Moss Life Cycle



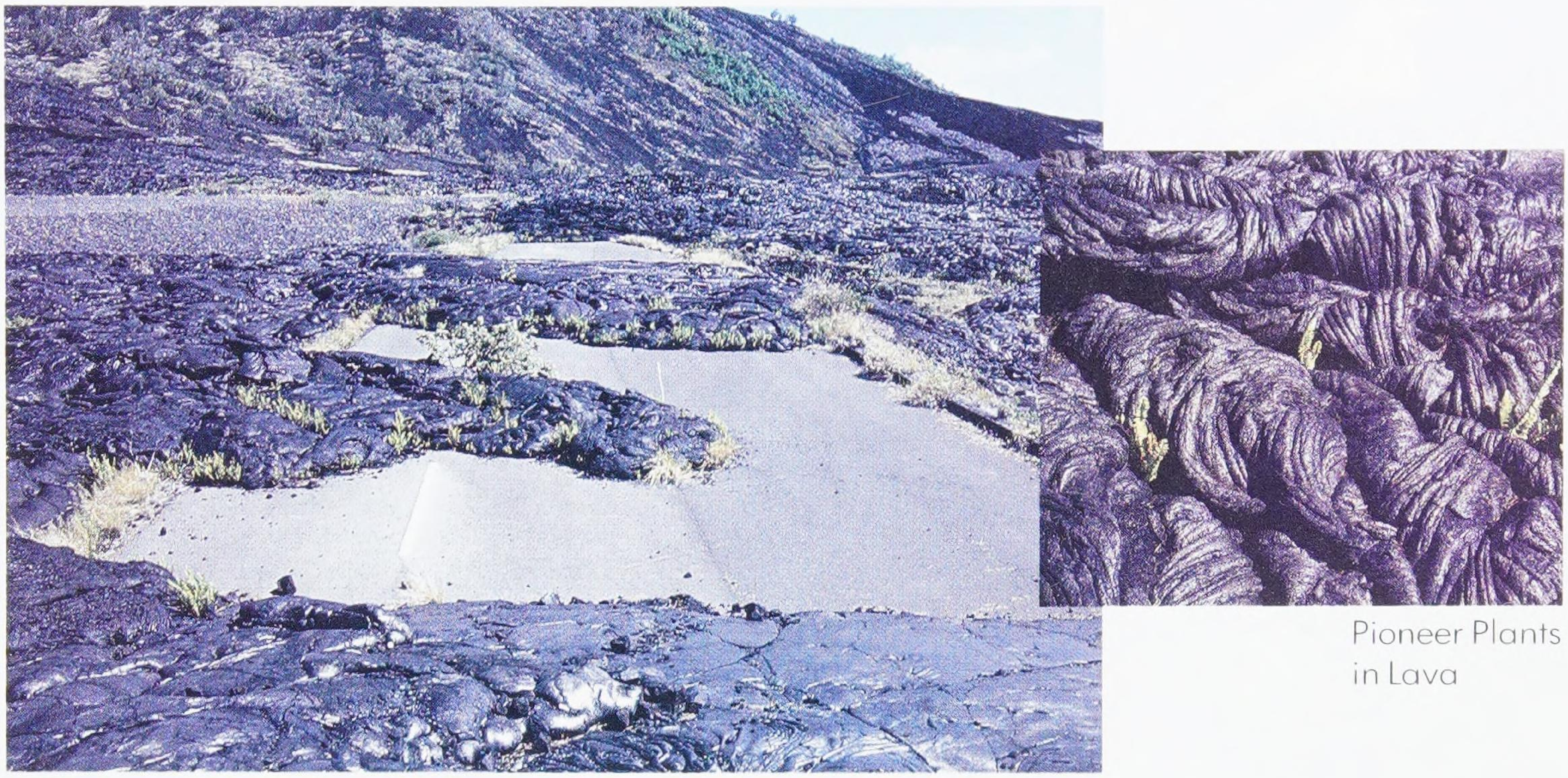

Pioneer Plants in Lava

Figure 10-10. Mosses and liverworts are pioneer plants that often are among the first living things to inhabit a new environment like this lava field.

Importance of Mosses and Liverworts

Mosses and liverworts are important in the ecology of many areas. They are often among the first plants to grow in new environments, such as lava fields, or disturbed environments, such as forests destroyed by fire. When a volcano erupts, the lava covers the land and destroys the plants living there. After the lava cools, the spores of mosses and liverworts are carried to the new rocks by the wind and begin to grow wherever there is enough water. When they grow on rocks, their rhizoids can actually begin to penetrate tiny cracks in the rocks' surfaces. Weathering of rocks often begins when mosses release chemicals that begin to break rocks down. Organisms that are the first to grow in new or disturbed areas like these are called **pioneer species.** Pioneer plant species grow and die and begin to build up decaying plant material that provides nutrients for other, less hardy, plants. That is, these pioneer plants change the conditions in the environment so that other plants can grow there, too. Eventually, larger vascular plants can begin to grow, sending their roots down through the decaying plants and into the rocks underneath. As the roots grow, they crack the rocks apart even more, and the weathering process slowly turns the rocks into new soil.

Connect to... Earth Science

Soil is a mixture of weathered rock and decaying organic matter (plant and animal). What roles do pioneer species such as lichens, mosses, and liverworts play in building soil?

ACTIVITY 10-1

Comparing Mosses and Liverworts

Problem: *How are mosses and liverworts similar?*

Materials

- hand lens
- forceps
- dropper
- 2 microscope slides
- microscope
- dissecting needle
- prepared slides of moss and liverwort gametophytes
- mosses
- liverworts
- water
- 2 coverslips

Procedure

1. Obtain a moss. The leafy part of the moss is the gametophyte. With a hand lens, *observe* the leafy body of the moss. Locate and observe the rhizoids.
2. Remove a piece of the leafy portion of the moss with a forceps and make a wet mount. Observe under low power and examine the cell layers.
3. Examine prepared slides of sections of the sporophyte and gametophyte moss plants under low and high power. Draw.
4. On the moss gametophyte, locate the capsule at the tip of the stalk. Remove the capsule and place it in a drop of water on a slide. Place a coverslip on the capsule. Using the eraser of your pencil, gently crush the capsule to release the spores. **CAUTION:** *Do not break the coverslip.* Observe the spores under low and high power. Draw and label the spores.
5. Obtain a liverwort. Repeat Steps 1-3.

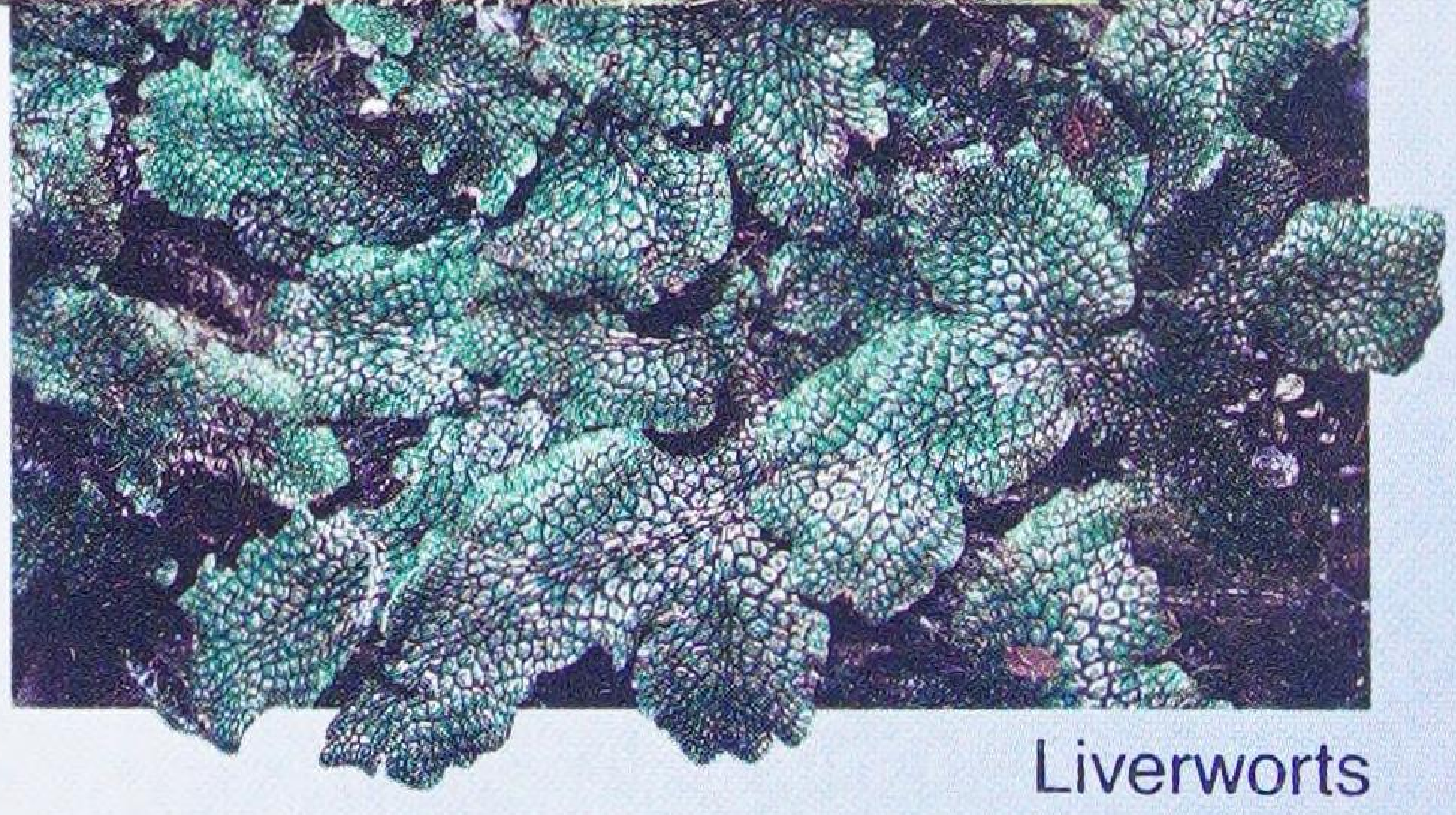
Analyze

1. How many cell layers were you able to observe in the moss? In the liverwort?
2. What function do the rhizoids have?
3. Where are spores formed in a moss?
4. Where are spores formed in a liverwort?

Data and Observations

Structure	Liverwort	Moss
Sporophyte		
Gametophyte		
Spores		

Mosses



Liverworts

Conclude and Apply

5. *Compare* the leafy structures of the mosses and liverworts.
6. *Compare* the rhizoids of mosses and liverworts.
7. How are the reproductive structures of the mosses and liverworts different?
8. How do the sporophytes of the mosses and liverworts *compare*?

Seedless Vascular Plants

A second and larger group of simple plants includes the seedless vascular plants. These plants differ from mosses mainly because they have vascular tissue. They differ from other vascular plants because they produce spores rather than seeds. The vascular tissue in the seedless vascular plants is made up of long, tube-like cells. These cells carry water, minerals, and nutrients to all the cells throughout the plant. Why is having cells like these an advantage to a plant? Remember that bryophytes are only a few cells thick. Each cell absorbs water directly from its environment. As a result, these plants do not grow very big. Plants with vascular tissue, on the other hand, can grow bigger and thicker because each cell gets water and nutrients through the vascular tissue.

What is vascular tissue?

Seedless vascular plants include the club mosses, spike mosses, horsetails, and ferns. Today, there are about 1000 species of club mosses, spike mosses, and horsetails. Ferns are more abundant, with at least 12 000 species known. During the Paleozoic era, there were many species that we now know of only from fossils. In the warm, moist Paleozoic era, some species of horsetails grew 15 meters tall. In contrast, simple vascular plant species today reach no more than 1 or 2 meters in height.

MINI-Lab

Where does water move in a plant?

Make a clean cut across the bottom of a celery stalk that has leaves. Put the cut end in a glass of water to which red food coloring has been added. Let the stalk stand overnight. *Observe* to see where the colored water has traveled in the plant. **In your Journal,** *relate* the movement of the water through the stalk to vascular tissue and describe where vascular tissue is located.

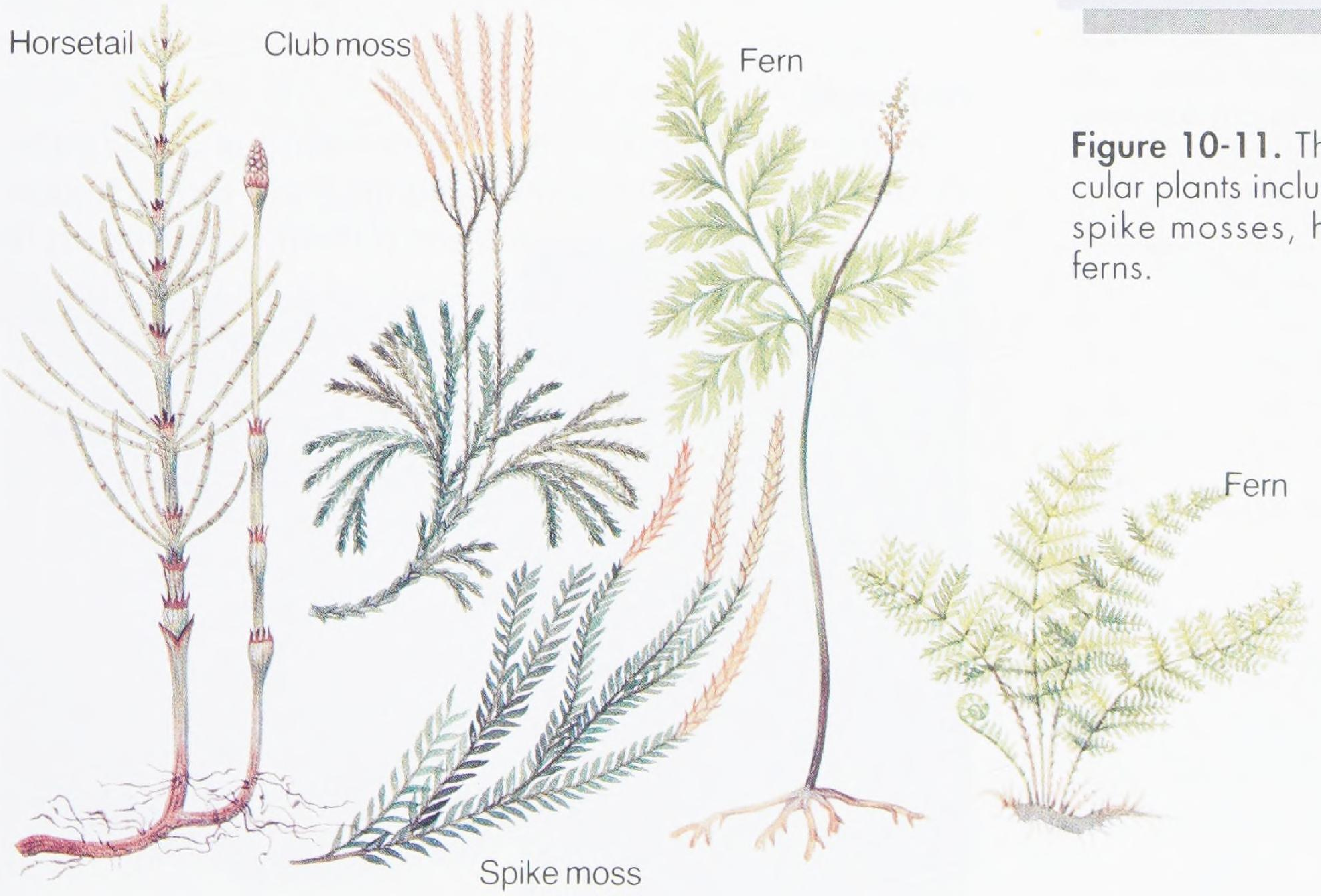


Figure 10-11. The seedless vascular plants include club mosses, spike mosses, horsetails, and ferns.

Club Mosses and Spike Mosses

Look at the photographs of club mosses and spike mosses in Figure 10-12. Club mosses produce spores at the end of the stems in structures that look like tiny pine cones. The upright stems of club mosses have needlelike leaves. One kind of club moss, *Lycopodium,* is called the ground pine because it looks like a miniature pine tree. *Lycopodium* is found from arctic regions to the tropics, but never in large numbers. In some areas *Lycopodium* is endangered because of overcollection. Most tropical species of *Lycopodium* are epiphytes. An **epiphyte** is a plant that grows on other plants for support.

Spike mosses look similar to club mosses. One species of spike moss, the resurrection plant, is adapted to desert conditions. When water isn't available, the plant curls up and looks dead. But when water falls in the desert, the resurrection plant unfurls its green leaves and begins making food again. The plant can go through this process many times if necessary.

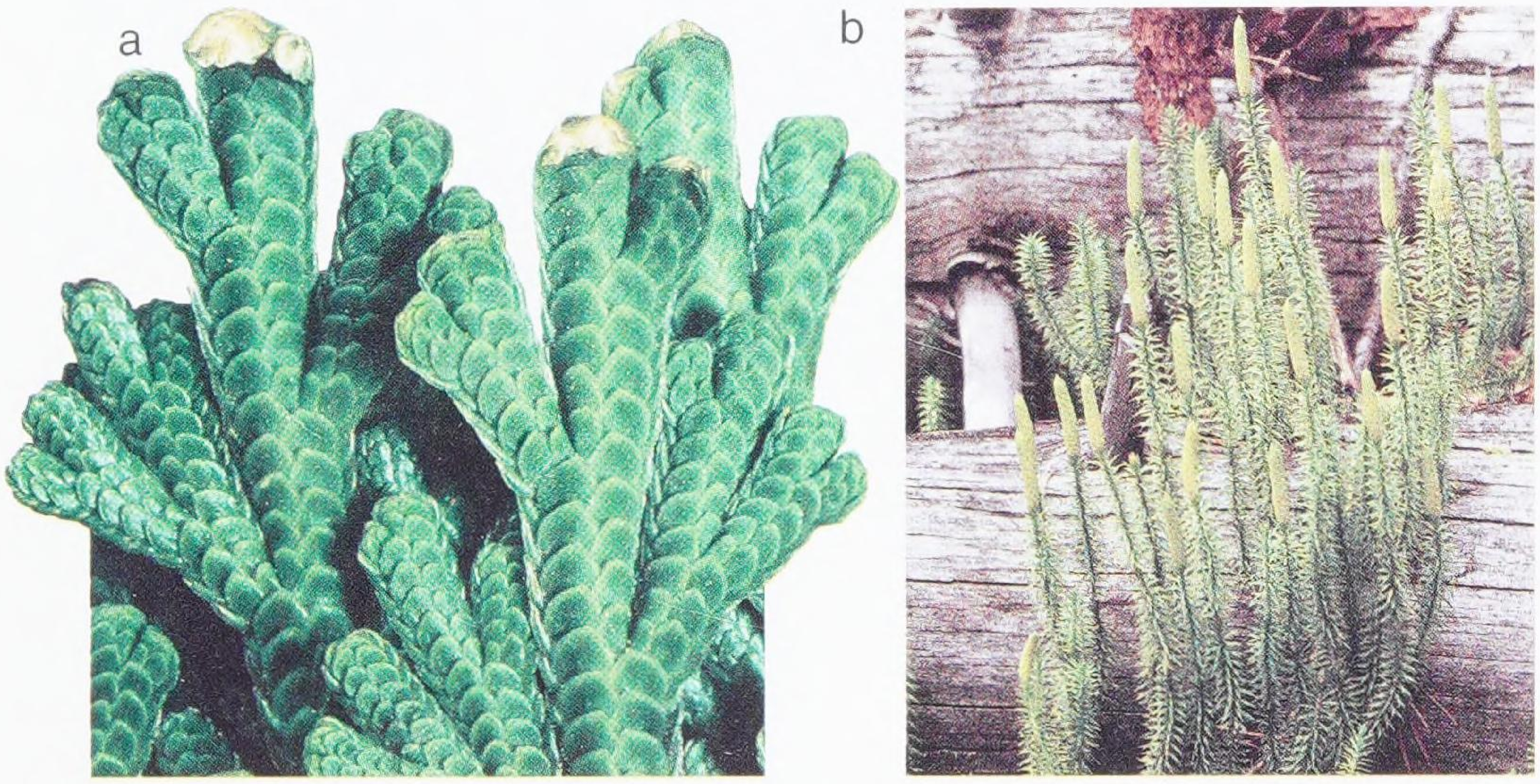


Figure 10-12. Club mosses (a) and spike mosses (b) produce spores at the end of stems in structures similar to pine cones. Early photographers often used the dry, flammable spores of club moss as flash powder to provide light to take photographs.

Horsetails

Horsetails have a stem structure unique among the vascular plants. Their stems are jointed and have a hollow center surrounded by a ring of vascular tissue. Leaves grow in a spiral around each joint. In Figure 10-13 you can see these joints easily. If you pull on a horsetail stem it will pop apart in sections. Spores grow in a structure at the tip of the stems, as in the club mosses. The stems of the horsetails contain silica, a gritty substance found in sand. In the days when

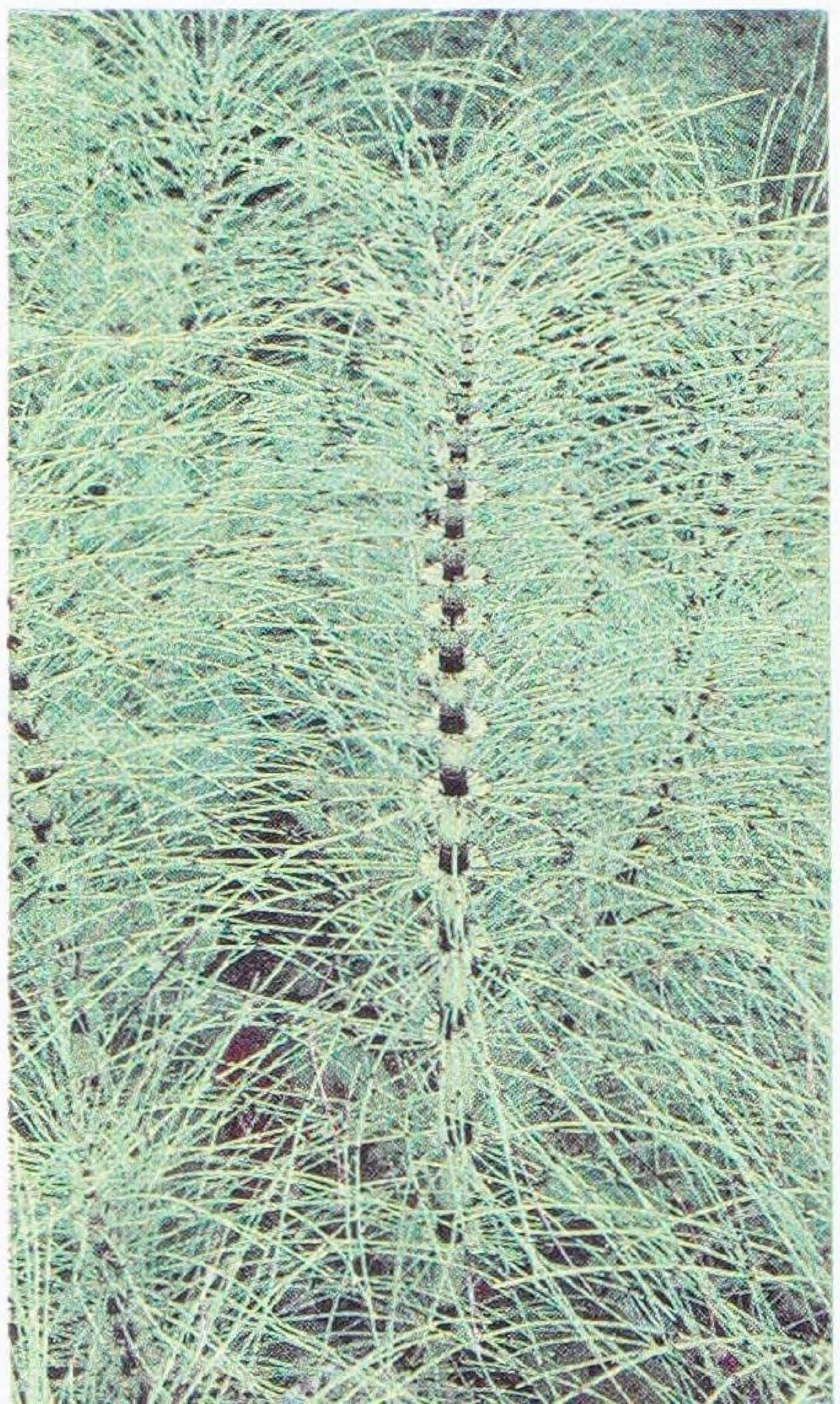


Figure 10-13. Horsetails contain silica and were used by pioneers in the United States to scrub pots and pans.

pioneers traveled westward across the United States, horsetail stems were used to scour pots and pans. The common name of *Equisetum* today is still "scouring rush."

Ferns

The largest group of seedless vascular plants is the division Pterophyta (teh ruh FITE uh), the ferns. There are about 12 000 living species of ferns, but like the other divisions of vascular plants, many more species are known only as fossils.

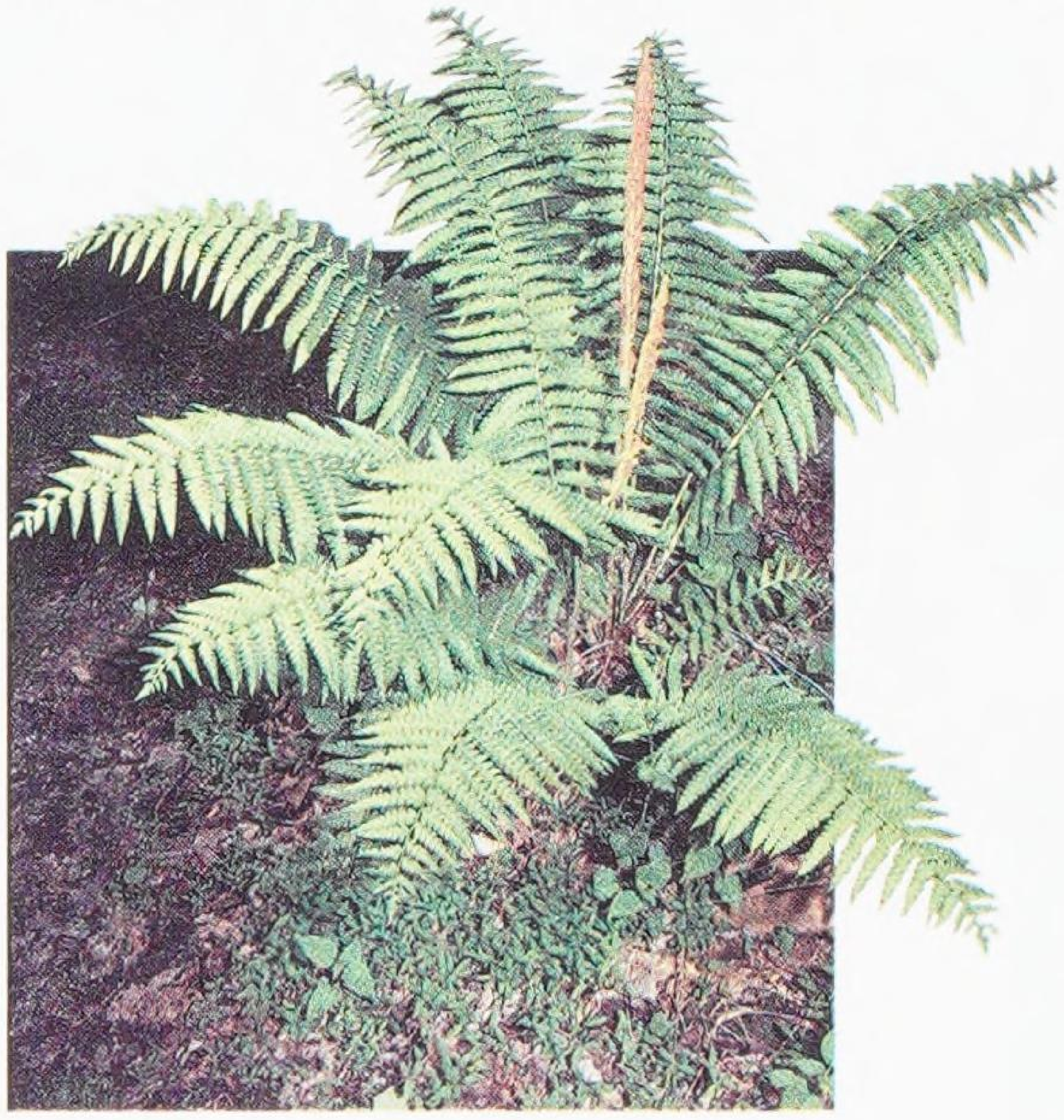


Figure 10-14. The unusual cinnamon fern bears its spores on separate stalks.

During the Carboniferous period of the Paleozoic era, most ferns grew much larger than any fern species alive at present. Species of tree ferns found today in tropical areas may reach 3 to 5 meters in height, but ancient tree ferns living in the swamps of the Carboniferous period grew as high as 25 meters. When they died, tree ferns and other plant species became submerged in water and mud before they could decompose. This plant material built up, became compacted and compressed, and eventually became coal. Today, a similar process is taking place in peat bogs. Coal and peat are two types of fuel used in many parts of the world today for energy. Coal, peat, petroleum, and natural gas are all known as fossil fuels because they were formed from the plants and other organisms of the Carboniferous period.

Connect to... Earth Science

Peat is an organic fuel found in Earth at the surface and to depths less than a hundred feet. Coal is found at a depth of a few hundred to a thousand feet. Oil is found from a thousand feet to seven thousand feet. Gas is found in the same depths as oil, but also to a depth of ten thousand feet. *Make a bar graph* to illustrate the depths at which each of these organic fuels is found.

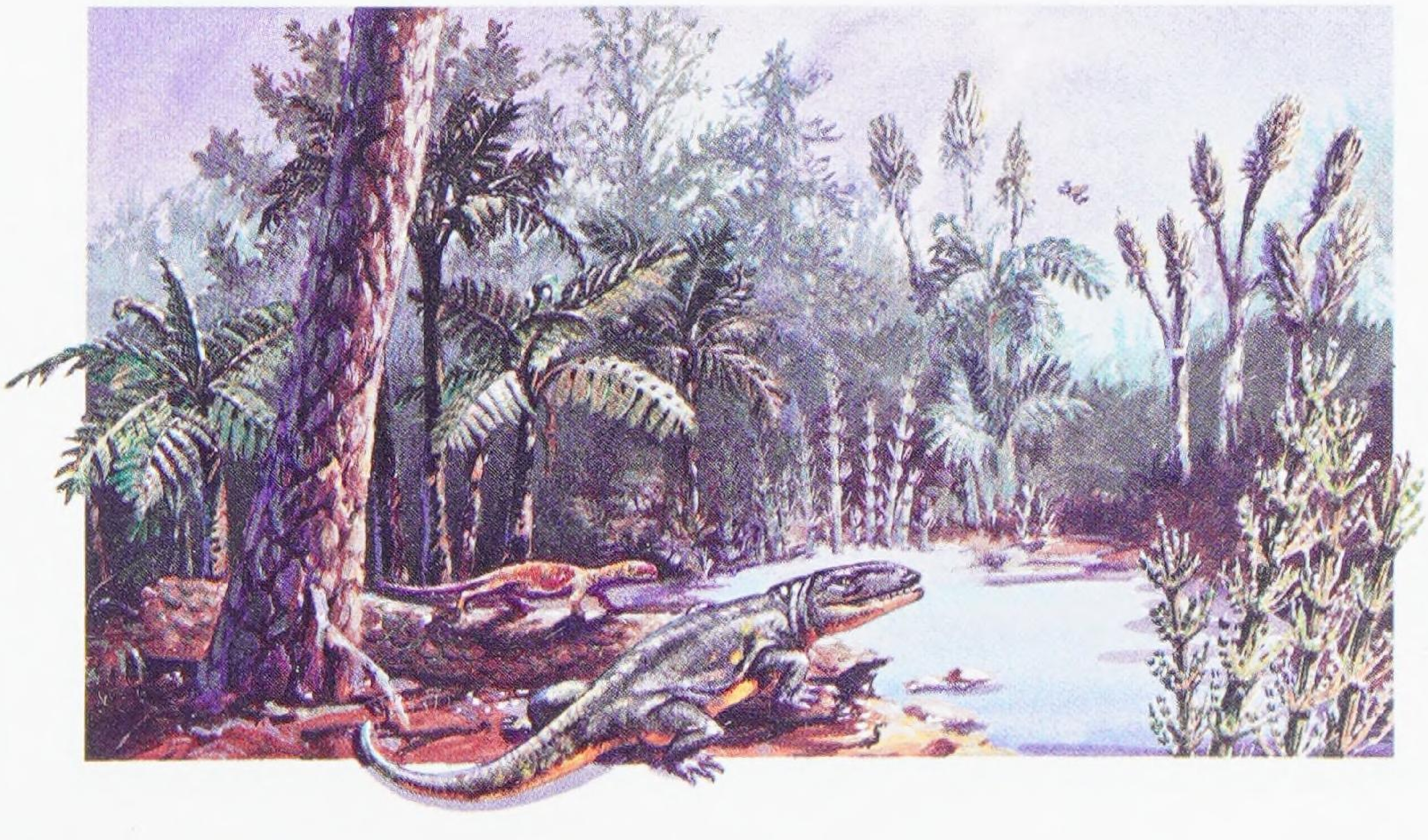


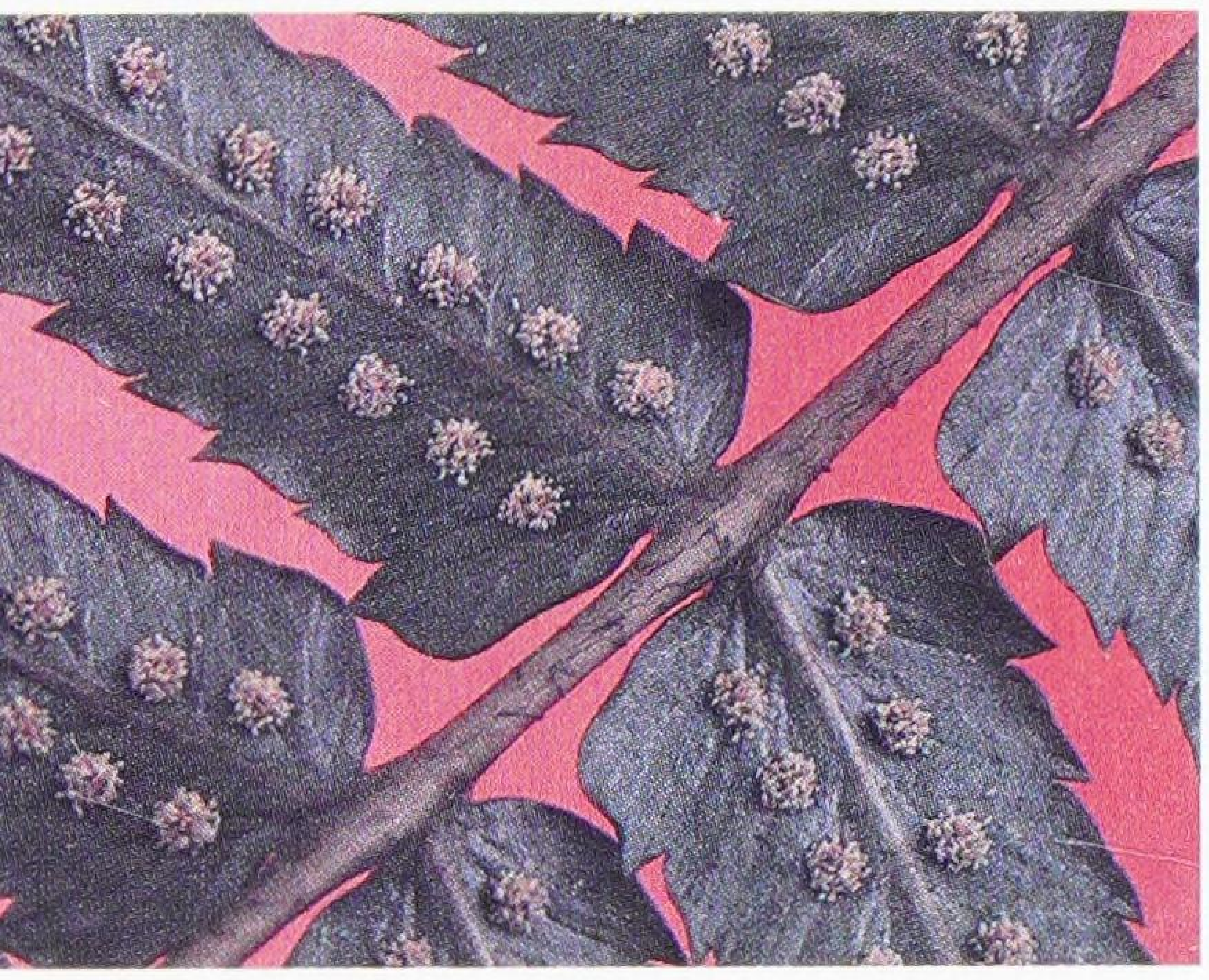
Figure 10-15. The Carboniferous swamp forest contained many more species of club mosses, spike mosses, horsetails, and ferns than are alive today.

The Fern Life Cycle

In the life cycle of a fern, the gametophyte and sporophyte do not depend on each other. This means that both forms of the fern plant can produce their own food. The fern plants that you may have seen growing in the woods or in an arrangement from a florist are the sporophytes. A fern has leaves that grow above the ground from an underground stem called a **rhizome.** Roots grow from the rhizome to anchor the plant in the soil. The leaf of a fern is called a **frond.** Young fronds are often called fiddleheads because their curled shape looks similar to the tops of violins, or fiddles. Ferns produce spores in structures called **sori** (*sing.* sorus) on the lower sides of the mature fronds. The sori usually look like crusty rust, brown, or blackish-colored bumps. When a sorus opens, spores are released at incredible speeds. They land on damp soil or rocks and germinate into small, green, heart-shaped gametophyte plants. The gametophyte is called a **prothallus.** The prothallus produces sex cells that unite to form the zygote. The zygote develops into the embryo, then sporophyte, as in the mosses. But in ferns, the gametophyte also produces new rhizomes, which can grow into the separate sporophyte fern plants you are familiar with. You can see the life cycle of a fern in Figure 10-16.

What is a frond?

Ferns are interesting to scientists because they have characteristics of both nonvascular and vascular plants. Like the bryophytes, ferns produce spores, yet they have



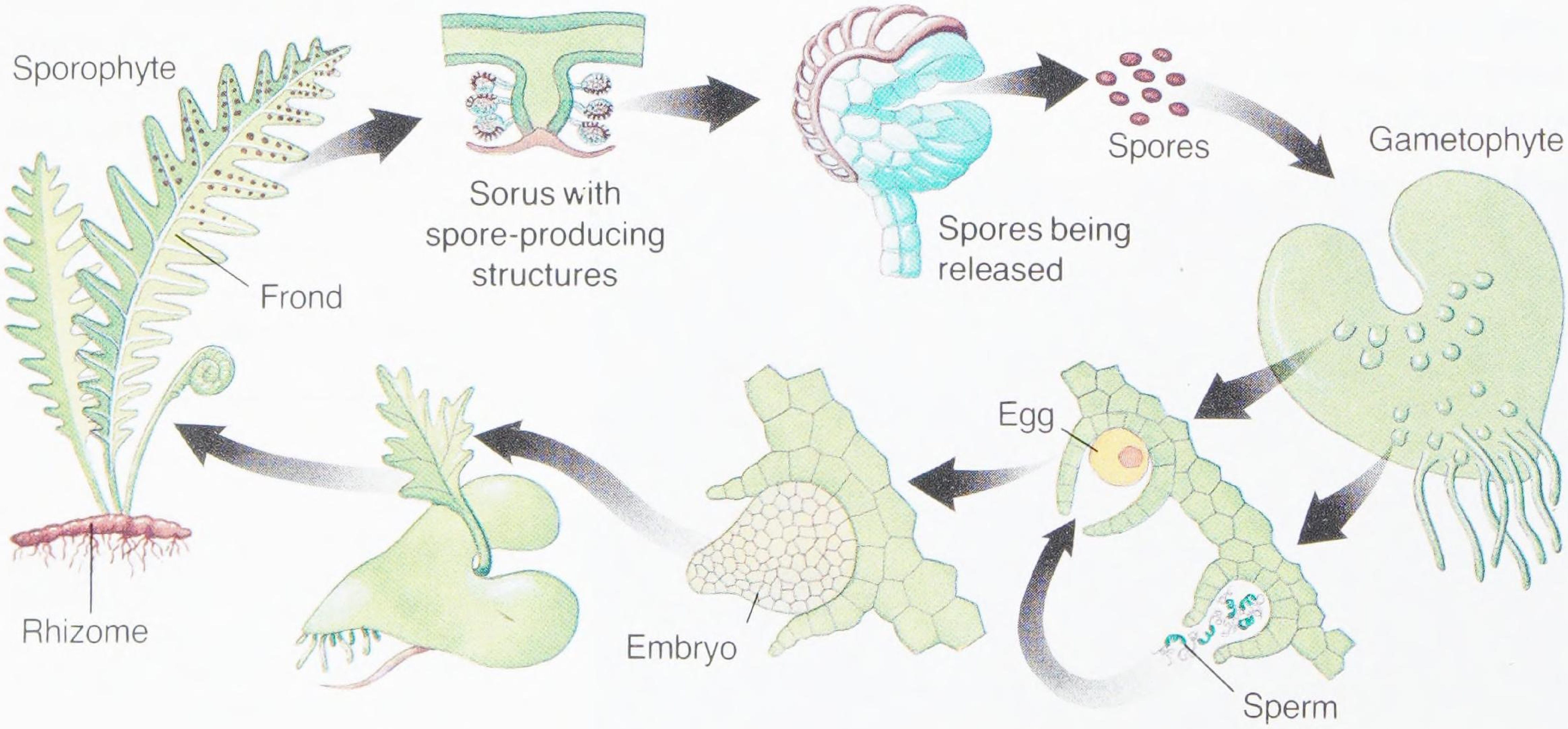


Figure 10-16. The Fern Life Cycle. Compare the position of the spore-producing structures on this fern with the cinnamon fern on page 243.

PROBLEM SOLVING

What is in Nature's Medicine Chest?

People in all cultures have found ways to treat illnesses, and many of these cures involve plants. Various native American cultures used willow bark to cure headaches. Heart problems were treated with foxglove in England, sea onions in Egypt, and seeds in Africa. In Peru, the bark of the cinchona tree was used to treat malaria. Scientists have found that many native cures are medically sound. Willow bark contains salicylates, the main ingredient in aspirin. Foxglove, sea onions, and the African seeds all contain digitalis or similar drugs. Cinchona bark contains quinine, an antimalarial drug.

Think Critically: How might the destruction of rain forests affect research for new drugs from plants?

vascular tissue like seed-bearing plants. Ferns have leaves (the fronds), stems (the rhizomes), and roots. If you were a scientist, how would you classify ferns?

SECTION REVIEW

1. Describe the life cycle of mosses.
2. How are club and spike mosses similar to mosses?
3. Explain the stages in the life cycle of a fern.
4. **Apply:** List ways simple plants affect your life each day. (HINT: Where do electricity and heat for homes come from?)
5. **Connect to Earth Science:** Plants are made up of materials supplied from soil. Horsetails contain large amounts of silica. What can you infer about the source of silica in horsetails?

Skill Builder

Concept Mapping

Make a concept map showing how nonvascular and vascular plants are related. Include these terms in the concept map: *plant kingdom, bryophytes, liverworts, mosses, seedless plants, nonvascular plants, seedless vascular plants, club mosses, ferns, horsetails,* and *spike mosses.* If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

SCIENCE & SOCIETY

10-3 Peat Moss as Fuel

New Science Words

bogs

Objectives

- State two advantages of using peat as fuel.
- Understand the environmental cost of using peat as fuel.

What's In a Bog?

What is a bog?

Bogs are very mysterious places. Human bodies 7000 years old have been recovered from these wet areas all over the world. Sound like the beginning of a horror movie? What exactly is a bog? **Bogs** are poorly drained areas with spongy, wet ground that is composed mainly of dead and decaying plants. The principal plants in bogs are nonvascular plants that belong to the genus *Sphagnum. Sphagnum* moss forms large mats on top of the water surface in bogs. The water in a bog is very acidic with little oxygen. These conditions slow down or stop the growth of the bacteria that would normally decompose dead organic matter. As a result, moss and other plants that die in bogs don't decay. Dead moss builds up in the bog and is compressed by the weight of the water above. Gradually the moss becomes peat, a combination of partially decaying sphagnum moss and other organisms. Peat has been used as a low-cost fuel for centuries. Blocks of black peat can be cut out of the bog, dried in the sun, then burned in a stove or furnace to produce heat. Peat is actually the first step in the geological process of turning plant material into coal. Lignite coal is formed when peat has been compressed and heated by the geologic force of Earth.

MINI-Lab

Does moss hold much water?

Place a few teaspoons of *Sphagnum* moss on a piece of cheesecloth. Twist the cheesecloth to form a ball and tie it securely. Weigh the ball. Put 200 mL of water in a beaker. Add the ball. *Predict* how much water the ball will absorb. Wait 15 minutes; remove the ball, draining off excess water. Weigh the ball and *measure* the amount of water left in the beaker. *Calculate* how much water the *Sphagnum* moss soaked up.

Peat has been used as a fuel for many years in Northern Europe, England, and Ireland. It is very cheap and burns slowly for long periods of time. After it is dried, the most decomposed peat burns with greater fuel efficiency than wood. Developing countries such as Burundi and Rwanda are looking into the use of peat as an alternative to importing expensive petroleum products. In the United States, geologists estimate that Maine has 300 000 hectares of peat available to use for fuel, whereas Minnesota has about three million hectares. In Maine, America's first peat-fueled power plant is already supplying energy to Boston. This is very economical for the New England area because oil, gas, and coal resources are all very far away.

Have we found the perfect source of fuel? Environmentalists don't think so. They fear that the bogs of the United States are headed toward the same fate as those in Ireland. Today, Ireland generates 21 percent of its electric power with peat. However, in the last 40 years, the Irish have destroyed 95 percent of their bogs. These bogs took nature 10 000 years to build! Why save bogs? They are home to animals and plants that can live no other place in the world. Bogs help control flooding by holding huge amounts of water. Peat moss can hold water in amounts up to 20 times its own dry weight. Bogs also help keep water resources such as rivers and lakes clean by filtering out silt and chemicals. Although peat is a cheap source of energy, it is a nonrenewable fossil fuel, just like coal, petroleum, and natural gas. When it burns, it releases chemicals such as carbon dioxide, sulfur dioxide, and nitrogen oxides, all sources of air pollution.

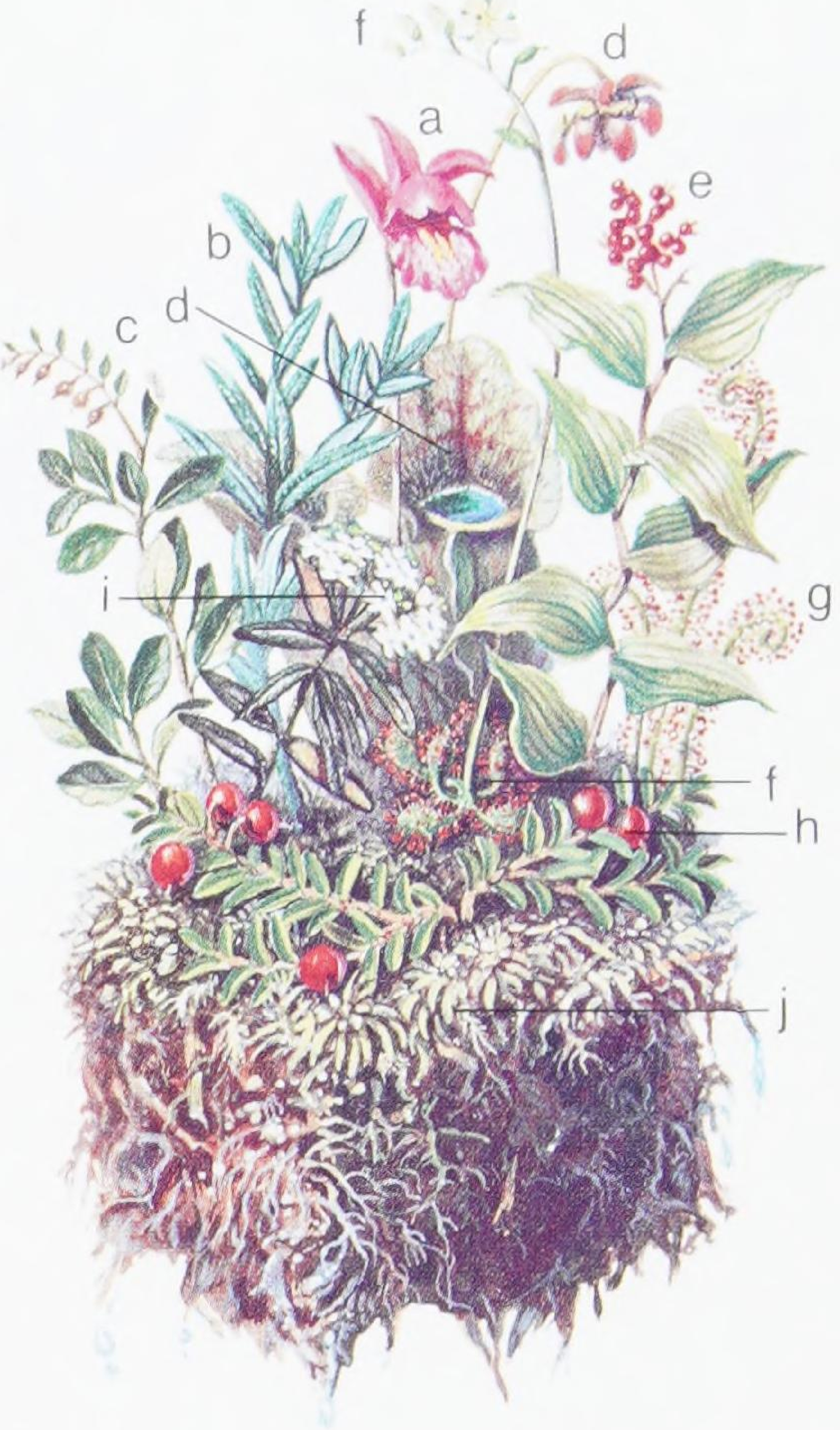


Figure 10-17. Unique plants of the peat bog include: (a) arethusa, (b) bog rosemary, (c)leather leaf, (d) pitcher plant, (e) false Solomon's seal, (f) sundew, (g) dewthread, (h) cranberry, (i) Labrador tea, and (j) *Sphagnum* moss.

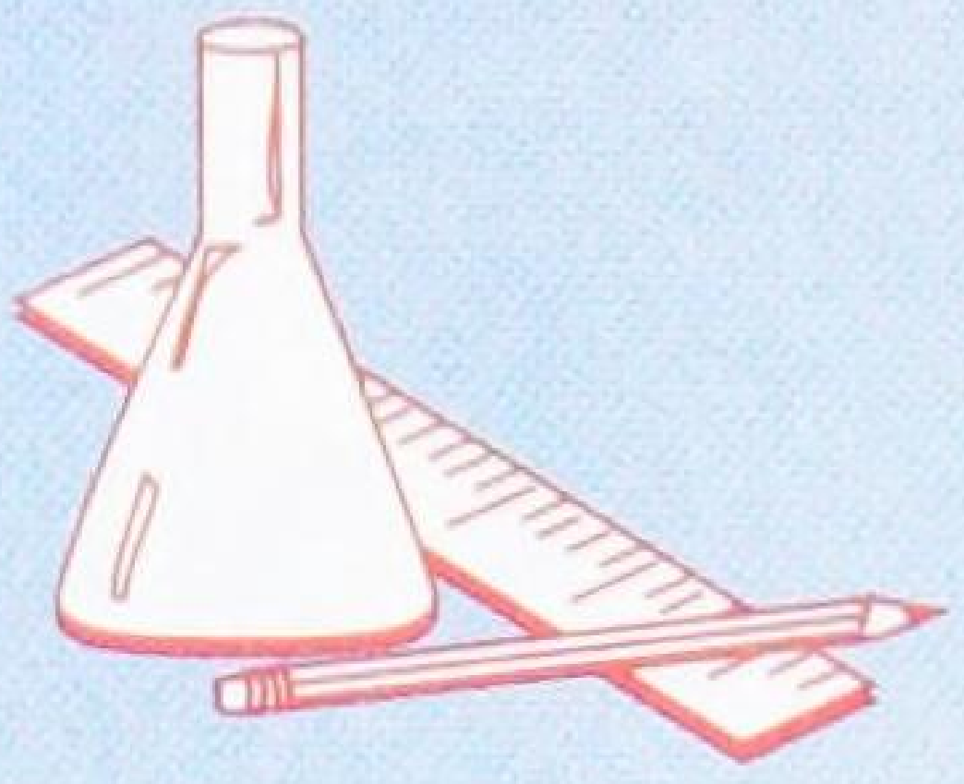
SECTION REVIEW

1. Why is peat considered a good alternative fuel?
2. Why are environmentalists concerned with its use?
3. **Connect to Earth Science:** Do you think *Sphagnum* in a bog has any potential anti-infection properties?

You Decide!

SCIENCE & SOCIETY

The state of Maine has certain environmental standards for peat harvesters. Maine peat has little sulfur and emits little sulfur dioxide. Excess water is captured in ponds to prevent runoff, and vegetation is to be restored to the area after the harvest. Are these sufficient trade-offs for losing bogs that took thousands of years to form?



ACTIVITY 10-2

The Life Cycle of a Fern

Problem: *How can stages in the life cycle of a fern be observed?*

Materials

- fern
- fern frond with spores
- fern spores
- hand lens
- petri dish
- paper towel
- scissors
- water
- prepared slides of fern
- microscope

Procedure

1. Cut a piece of paper towel into a circle that will just fit into the bottom of the petri dish.
2. Soak the paper towel circle with water. Use your fingernail to gently scrape away the protective membrane of the sori on a fern frond. Tap the sori to dislodge the spores.
3. Sprinkle a few fern spores on the paper towel and cover the petri dish. *Observe* the spores in the petri dish with a hand lens once each week for 6 weeks. Add water if necessary.
4. Make a data table like the one shown. Draw and label what you see in the petri dish each week. Write your observations in the table.
5. *Observe* the fronds of the fern plant for evidence that it is a sporophyte.
6. Use the microscope to look at prepared slides of the fern life cycle under low and high power.

Analyze

1. In which stage in the life cycle of a fern are spores formed?
2. In which stage are sex organs formed?
3. What is the name given to fern leaves?
4. What is the name of the underground stem?

Data and Observations

Week	Fern Gametophyte	Fern Sporophyte
1		
2		
3		
4		
5		
6		

Conclude and Apply

5. *Compare and contrast* rhizoids and rhizomes.
6. *Compare* the sporophyte with the gametophyte of a fern.
7. What advantage is there to having fern spores shot out of the sori?

CHAPTER REVIEW

SUMMARY

10-1: Characteristics of Plants

1. Plants are many-celled eukaryotes adapted to life on land.

2. Plants evolved from the plantlike protists.

3. Simple plants include nonvascular plants, the bryophytes, and vascular plants with vessels that conduct materials to plant cells.

10-2: Seedless Plants

1. Bryophytes—mosses and liverworts—reproduce through the process of alternation of generations, as do all plants.

2. Ferns, club mosses, and horsetails are seedless vascular plants with vascular tissue.

3. Nonvascular plants are pioneer species that help to break down rock into soil for other plants. Simple vascular plants have characteristics of both nonvascular and vascular plants.

10-3: Science and Society: Peat Moss as Fuel

1. Peat is a cheap fuel that burns slowly for long periods of time. It is available in places that are far away from oil, gas, or coal resources.

2. Bogs are important homes for unique organisms, hold water to prevent flooding, and help filter out silt and chemicals in water.

KEY SCIENCE WORDS

a. **alternation of generations**
b. **bogs**
c. **cellulose**
d. **cuticle**
e. **epiphyte**
f. **frond**
g. **gametophyte**
h. **nonvascular plants**
i. **pioneer species**
j. **rhizoids**
k. **rhizome**
l. **sori**
m. **sporophyte**
n. **vascular plants**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. plant that produces sex cells
2. wet ground made of dead, non-decaying plants
3. plant that produces spores
4. rootlike filaments
5. underground fern stem
6. spore-producing capsules
7. plants containing tube-like conducting cells
8. plant division including mosses and liverworts
9. the first plants to grow in new environments
10. waxy layer on stems and leaves

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. Roots, cell walls of cellulose, and having many cells are examples of _______ characteristics.
a. moneran **c.** animal
b. protist **d.** plant

2. Plants probably evolved from _______.
a. animals **c.** fungi
b. protists **d.** monerans

3. _______ are plants only a few cells thick.
a. Bryophytes **c.** Horsetails
b. Ferns **d.** Vascular

4. _______ plants are plants with vessels.
a. Bryophyte **c.** Nonvascular
b. Moss **d.** Vascular

5. Nonvascular plants have all but _______.
a. zygotes **c.** rhizoids
b. rhizomes **d.** roots

6. Plants without vascular tissues are _______.
a. ferns **c.** moss
b. liverworts **d.** nonvascular

7. Ferns reproduce by forming _______.
a. spores **c.** seeds
b. vascular tissue **d.** flowers

8. _______ are seedless vascular plants.
a. Mosses **c.** Horsetails
b. Liverworts **d.** Oaks

9. Of these, ferns do not have _______.
a. fronds **c.** rhizomes
b. rhizoids **d.** spores

10. All plants have a life cycle with _______.
a. seeds **c.** flowers
b. fruits **d.** alternation of generations

USING LAB SKILLS

11. Design an experiment using celery stalks with leaves, a sharp knife, water with food coloring, and a timer to determine the rate at which water moves up through vessels. Describe and record your experiment in your Journal.

12. Graph the data from the MINI-Lab on page 246 to compare the weight of the mass of Sphagnum before and after water is absorbed, or the amount of water in the beaker or jar before and after.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Why is it an advantage for simple plants to alternate generations?

14. Why are sporophytes dependent on the gametophytes in bryophytes?

15. What would happen if a land plant's waxy cuticle was destroyed?

16. Compare how the cells of nonvascular and vascular plants obtain water.

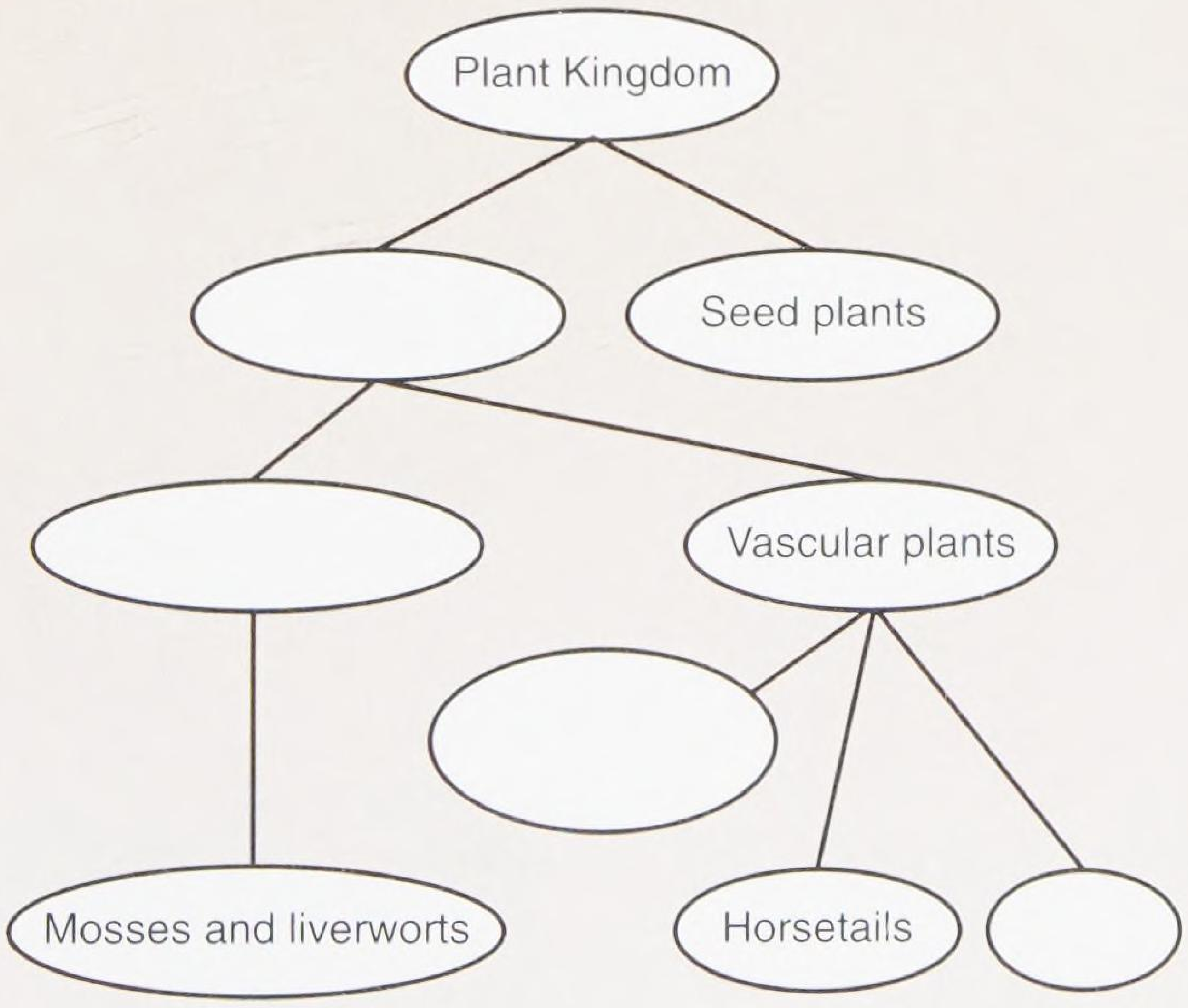
APPLY

17. Human remains sometimes found in peat bogs are very well-preserved. Explain why this occurs.
18. Discuss the importance of water in reproduction of bryophytes and ferns.
19. Why is *Sphagnum* moss added to garden soil?
20. Explain why mosses are found on moist forest floors.
21. How do mosses change rocky areas so that other plants can take root?

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Concept Mapping:** Fill in the map showing the divisions of the Plant Kingdom.



2. **Classifying:** Classify these plants in the correct group, bryophytes or seedless vascular: 1. club moss, 2. fern, 3. liverwort, 4. *Equisetum*, 5. horsetail, 6. *Lycopodium*, 7. moss, 8. spikemoss, 9. *Sphagnum*, 10. peat moss
3. **Sequencing:** Put the steps of the moss life cycle in sequence starting with the sporophyte stage.
4. **Making and Using Graphs:** Make a pie graph using the data below.

Simple Plants	Number of Species
Bryophytes	20 000
Club mosses, spike mosses, and horsetails	1000
Ferns	12 000
Total	33 000

PROJECTS

1. Develop a model of how coal is formed. Include a time line and a map of the parts of the U.S. where coal mines are located. Obtain samples of "soft" and "hard" coal and describe differences in their composition, origin, and formation.
2. Go for a walk in the woods and see how many different kinds of mosses there are. List the locations and conditions under which each is found growing.

CHAPTER

11 The Seed Plants

What's inside a seed? Are there green leaves, stems, and roots in a seed? Is a seed anything like a full-grown plant?

FIND OUT!

Do this simple activity to find out what's in a seed.

Obtain a raw peanut that is still in its shell. Peanuts are seeds, and shells are dried fruit. Open the shell and *observe* the seeds. Take the reddish-brown papery covering off one of the peanuts. Carefully pull apart the halves of the peanut. Look for a small bump on one half. This is the embryo plant. *Identify* parts that you think will become leaves, a stem, or roots.

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 11-1 Seed Plants
- What Is a Seed Plant?
- Gymnosperms
- Angiosperms
- Origin and Evolution of Seed Plants
- Importance of Seed Plants

Section 11-2 Parts of Complex Plants
- Roots
- Stems
- Leaves

Section 11-3 Seed Plant Reproduction
- Gymnosperm Reproduction
- Angiosperm Reproduction

Section 11-4 Science and Society
Effects of Acid Rain
- Acid Rain: An International Problem

Previewing Science Skills

- In the **Skill Builders,** you will compare and contrast, classify, and hypothesize.
- In the **Activities,** you will observe, analyze, collect and interpret data, and compare.
- In the **MINI-Labs,** you will observe and describe.

What's next?

Now you know that a seed contains an embryo plant. In this chapter you'll learn about the kinds of plants that make seeds, how seed plants are important in the environment, and how the evolutionary history of seed plants is related to the evolution of other organisms.

11-1 Seed Plants

New Science Words

gymnosperms
angiosperms
monocots
dicots

Objectives

- List the main characteristics of seed plants.
- Describe the main characteristics of gymnosperms and angiosperms and their importance.
- Compare the evolution of gymnosperms and angiosperms.

What Is a Seed Plant?

Have you ever eaten Chinese vegetables like those shown in Figure 11-1? These vegetables include bamboo shoots, water chestnuts, and snow peas. In the Philippines and Malaysia, coconut milk and banana flowers are used in many dishes. Corn and beans are staple foods in Mexico. All of these foods came from seed plants. What fruits and vegetables have you eaten today? If you had an apple, a peanut butter and jelly sandwich, and a glass of orange juice for lunch, you ate foods that came from seed plants.

How are seed plants different from simple plants?

Nearly all the plants you are familiar with are seed plants. There are about 235 000 known species of seed plants in the world. Seed plants have roots, stems, leaves, and vascular tissue. What makes a seed plant different from simple plants is that it grows from a seed. A seed is the reproductive part of a plant that contains a plant embryo and stored food. Within a seed are all the parts needed to produce a new plant.

Figure 11-1. Plants like these provide food for humans and most other consumers on Earth.

Most scientists classify seed plants into two major groups, the gymnosperms and angiosperms. Both of these groups produce seeds, but you will see that they have some very important differences.

Gymnosperms

The oldest trees alive today are gymnosperms (JIHM nuh spurmz)—in fact, there's one bristlecone pine tree in the White Mountains of eastern California that is 4900 years old. **Gymnosperms** are vascular plants that produce seeds on the scales of cones. The word *gymnosperm* comes from the Greek language and means "naked seed." Seeds of gymnosperms are not protected by a fruit. Gymnosperms do not produce flowers. Leaves of most gymnosperms are needlelike or scalelike. Most gymnosperms are evergreen plants that keep their leaves for several years.

What are gymnosperms?

Gymnosperms include four divisions of plants—the conifers, cycads, ginkgos, and gnetophytes. Of these, you are probably most familiar with the pines, firs, spruces, cedars, and junipers in the division Coniferophyta (KAHN uh fur AHF uh tuh). This division contains the greatest number of species of gymnosperms. Some conifers produce male and female cones on separate trees, but other species produce both types of cones on the same tree. Figure 11-2 shows examples of the four divisions of gymnosperms.

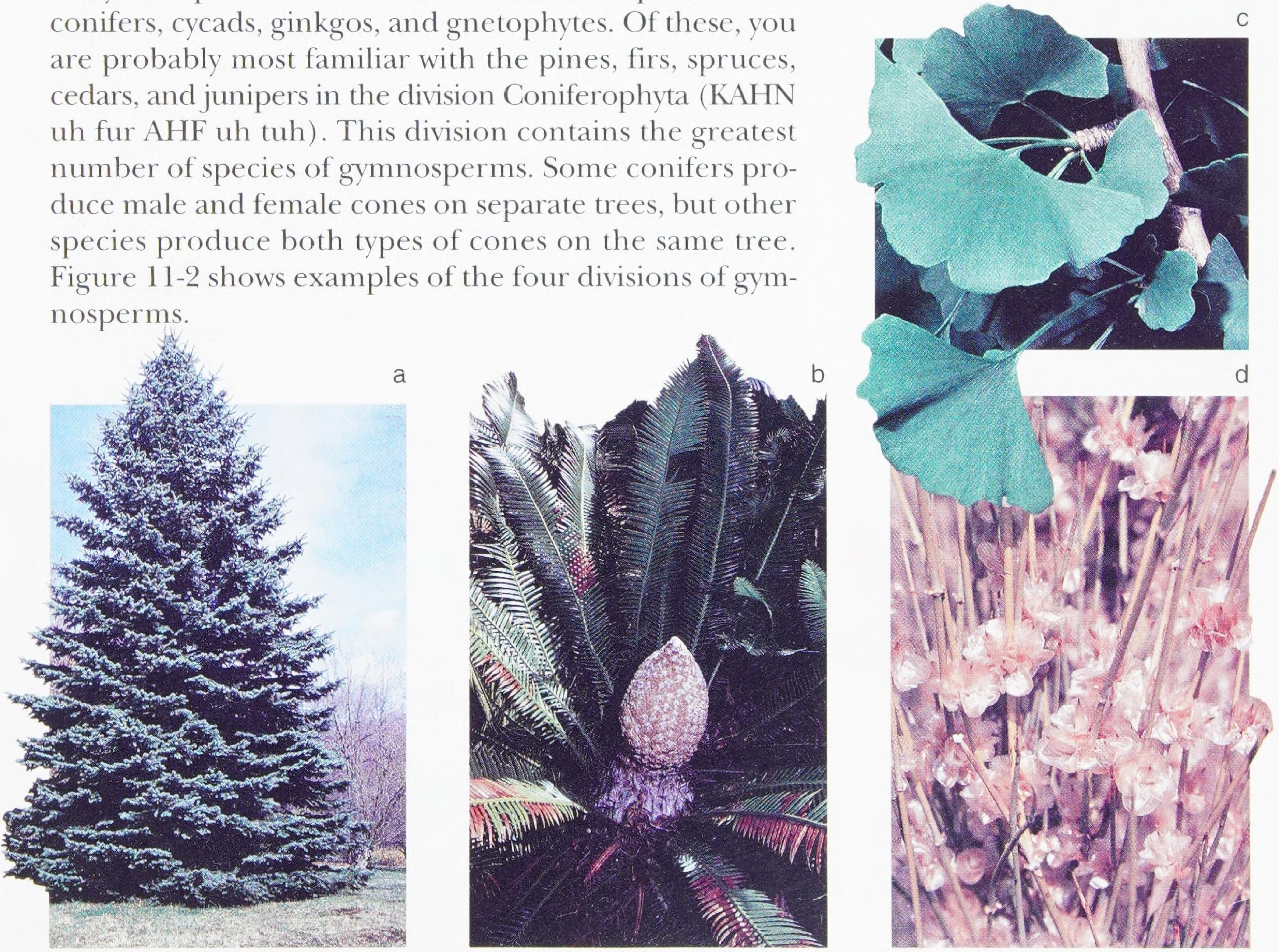


Figure 11-2. The gymnosperms include conifers (a), cycads (b), ginkgos (c), and gnetophytes (d).

Angiosperms

What are angiosperms?

When you bite into a pear or an apple, you are eating part of an angiosperm (AN jee uh spurm). **Angiosperms** are vascular plants in which the seed is enclosed inside a fruit. A fruit is a ripened ovary, the part of the plant where seeds are formed. If you eat most of your pear or apple, you'll find seeds inside. All angiosperms produce flowers and are classified in the division Anthophyta (an THAWF uh tuh). More than half of all known plant species are angiosperms.

There are two classes of angiosperms, or flowering plants: the monocots (MAHN uh kahts) and the dicots (DI kahts). The terms *monocot* and *dicot* are shortened forms of the words monocotyledon and dicotyledon. A cotyledon is a seed leaf inside a seed. **Monocots** have one seed leaf inside their seeds; **dicots** have two. Monocots are flowering plants with flower parts in threes and vascular bundles throughout the stems. The scattered bundles show up as parallel veins in their narrow leaves. If you had cereal for breakfast this morning, you ate a bowlful of monocot seeds! Cereal grains such as corn, rice, oats, and wheat are all monocots.

Dicots are flowering plants with flower parts in fours or fives and vascular bundles in rings inside the stems. The bundles show up as branching, netlike veins in the broad dicot leaves. Examples of dicots include trees like oaks and maples, vegetables like lettuce and beans, fruits like watermelons and oranges, and many garden flowers.

In Your JOURNAL

The collection of grass clippings as part of garbage placed in landfills has become a big environmental issue. Study the issue. Then, **in your Journal,** write a rough draft of a letter to the editor of your local paper supporting one side or the other. Make a clean copy and send it to the paper.

Figure 11-3. The Characteristics of Monocots and Dicots

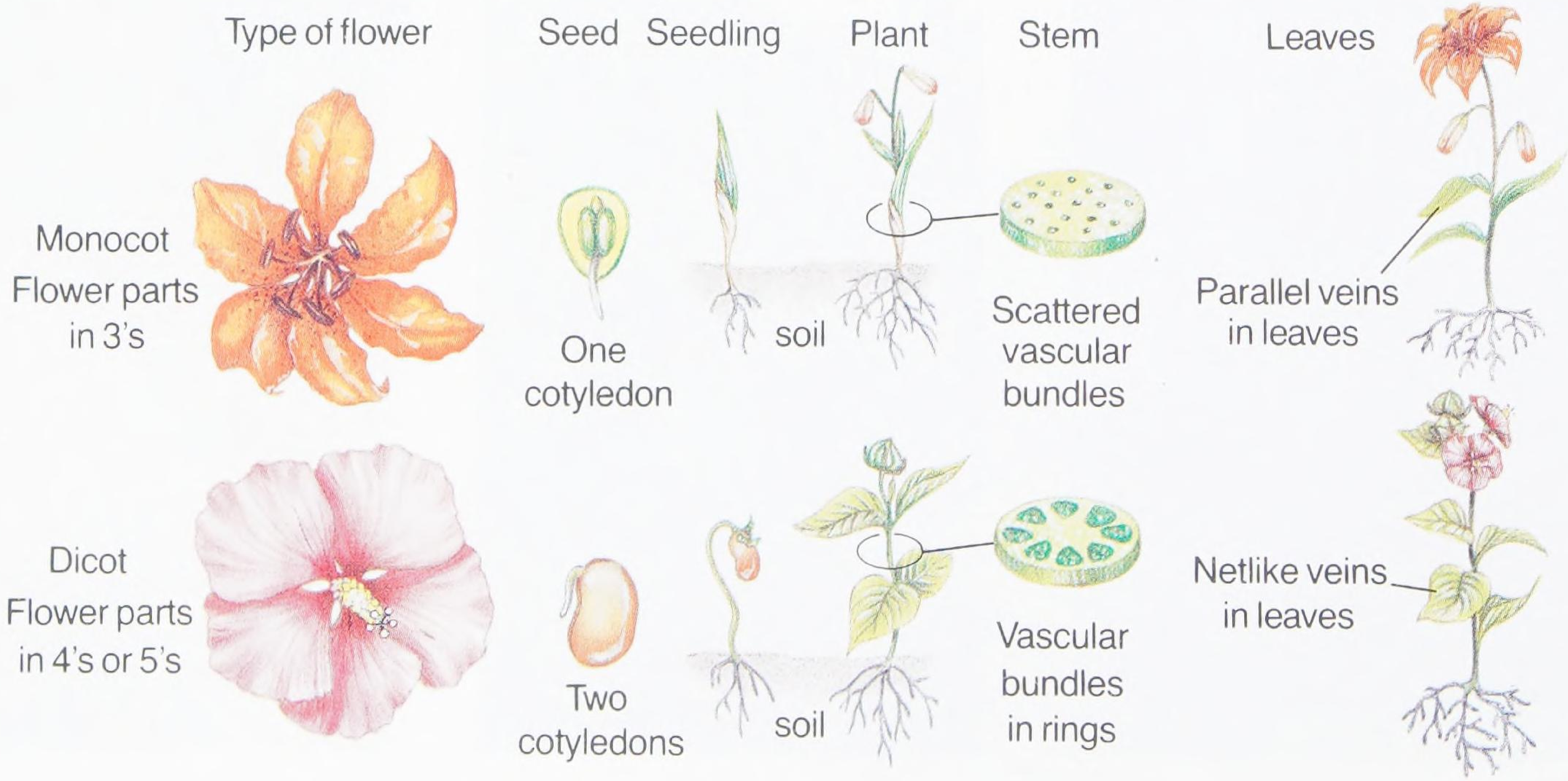

Type of flower
Seed
Seedling
Plant
Stem
Leaves
Monocot
Flower parts in 3's
One cotyledon
soil
Scattered vascular bundles
Parallel veins in leaves
Dicot
Flower parts in 4's or 5's
Two cotyledons
soil
Vascular bundles in rings
Netlike veins in leaves

Figure 11-4. Rice is a staple food crop for humans worldwide. Ninety percent of all rice is grown in Asia, but, in the United States, Texas and California are major producers.

Origin and Evolution of Seed Plants

Seed plants have some different needs from those of simple vascular plants like ferns. For example, ferns depend on water for reproduction, but seed plants do not. A seed is an adaptation that gives plants the ability to survive on land away from bodies of water. Gymnosperms and angiosperms today are found in tropical, temperate, and even extremely dry or cold environments.

Gymnosperms probably evolved from a group of plants that grew about 350 million years ago. Cycads and conifers have been found in the fossil record since the Paleozoic era, 200 million years ago. Flowering plants did not exist until the Cretaceous period, about 120 million years ago. Gaps in the fossil record prevent scientists from tracing the exact origins of flowering plants. After their appearance in the Cretaceous period, angiosperms evolved into many different forms. Today they are the most common form of plant life on Earth.

Importance of Seed Plants

Imagine that your class is having a picnic in the park. You cover the picnic table with a red-checked tablecloth and pass out paper cups and plates. You toast hot dogs and buns, eat potato chips, and drink apple cider. Perhaps you collect leaves or flowers for a science project. Later you clean up and put leftovers in paper bags.

Connect to... Chemistry

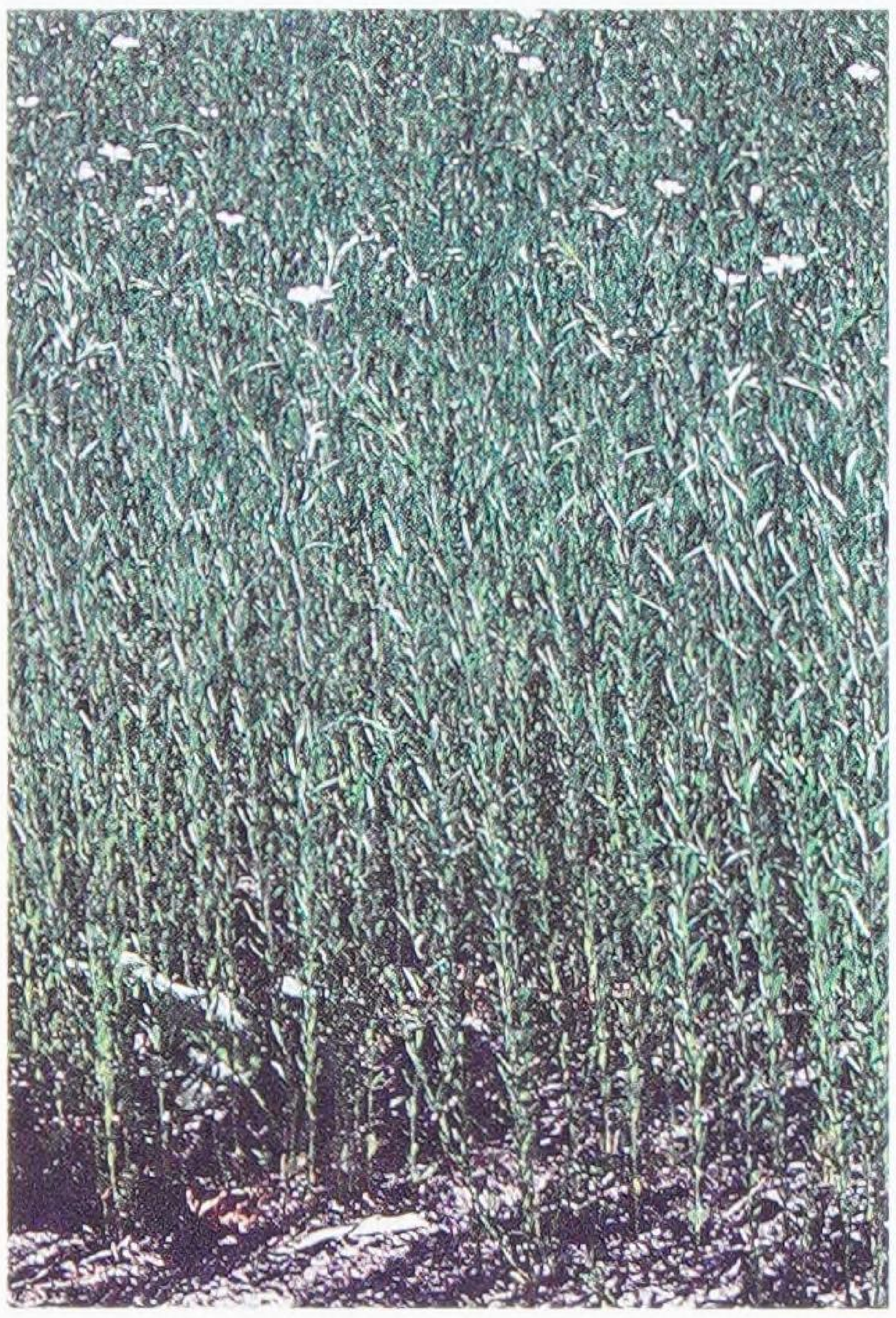
Throughout history, different cultures have depended on grains as the basis of their diets. Find out what complex carbohydrate is common to many grains such as corn, beans, and rice.

Now let's imagine this scene if there were no seed plants on Earth. There would be no picnic table and no pulp to make paper products such as cups, plates, and bags. Bread for buns, apples for cider, and potatoes for chips all come from plants. The tablecloth is made of cotton, a plant. Without seed plants, there would be no picnic!

On a global scale, conifers are the most economically important gymnosperms. Most of the wood used for building construction and for paper production comes from conifers such as pines and spruces. Resin, a waxy substance secreted by conifers, is used to make chemicals found in soap, paint, varnish, and some medicines.

The most common plants on Earth are the angiosperms. They are important to all life because they form the basis for the diets of most animals. Grains such as barley and wheat and legumes such as peas and beans were the first plants ever grown by humans. Angiosperms take in huge amounts of carbon dioxide for photosynthesis and release oxygen needed by other organisms. Many of the fibers used in clothing such as flax and cotton fibers come from angiosperms. Angiosperms are used in the production of medicines, rubber, oils, perfumes, pesticides, and some industrial chemicals.

Figure 11-5. Linen, a type of cloth, is made from fibers of the flax plant, *Linum usitatissimum*.



SECTION REVIEW

1. What are the main characteristics of a seed plant?
2. Make a chart to compare the characteristics of gymnosperms and angiosperms.
3. Give three reasons why seed plants are important.
4. **Apply:** The fruit of the ginkgo has an unpleasant smell, so only male trees are planted near homes. Why?
5. **Connect to Earth Science:** Use the geologic time scale on page 139 to find out during what period, the first seed plants evolved.

Skill Builder

Comparing and Contrasting

Monocots and dicots have some similarities and differences. Compare and contrast these two classes of plants. If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.

Parts of Complex Plants

11-2

Objectives

- Describe the structures of roots, stems, and leaves.
- Describe the functions of roots, stems, and leaves.
- Explain some unique adaptations of roots, stems, and leaves.

New Science Words

xylem
phloem
cambium
stomata
guard cells

Roots

Imagine a large tree growing alone on top of a hill. What is the largest part? Chances are you named the trunk or the branches. But did you consider the roots? The root systems of most plants are as large or larger than the aboveground stems and leaves. Why do you think root systems are so large?

Why are roots so important to plants? All the water and minerals used by a plant enter by way of its roots. Roots have vascular tissue to move water and minerals from the ground up through the stems to the leaves. Roots also anchor plants in soil. If they didn't, plants could be blown away by wind, or washed away by water. Each root system must support the plant parts that are above the ground—the stem, branches, and leaves of a tree, for example. In Figure 11-6, you can see the root system of a dandelion as compared with the rest of the plant.

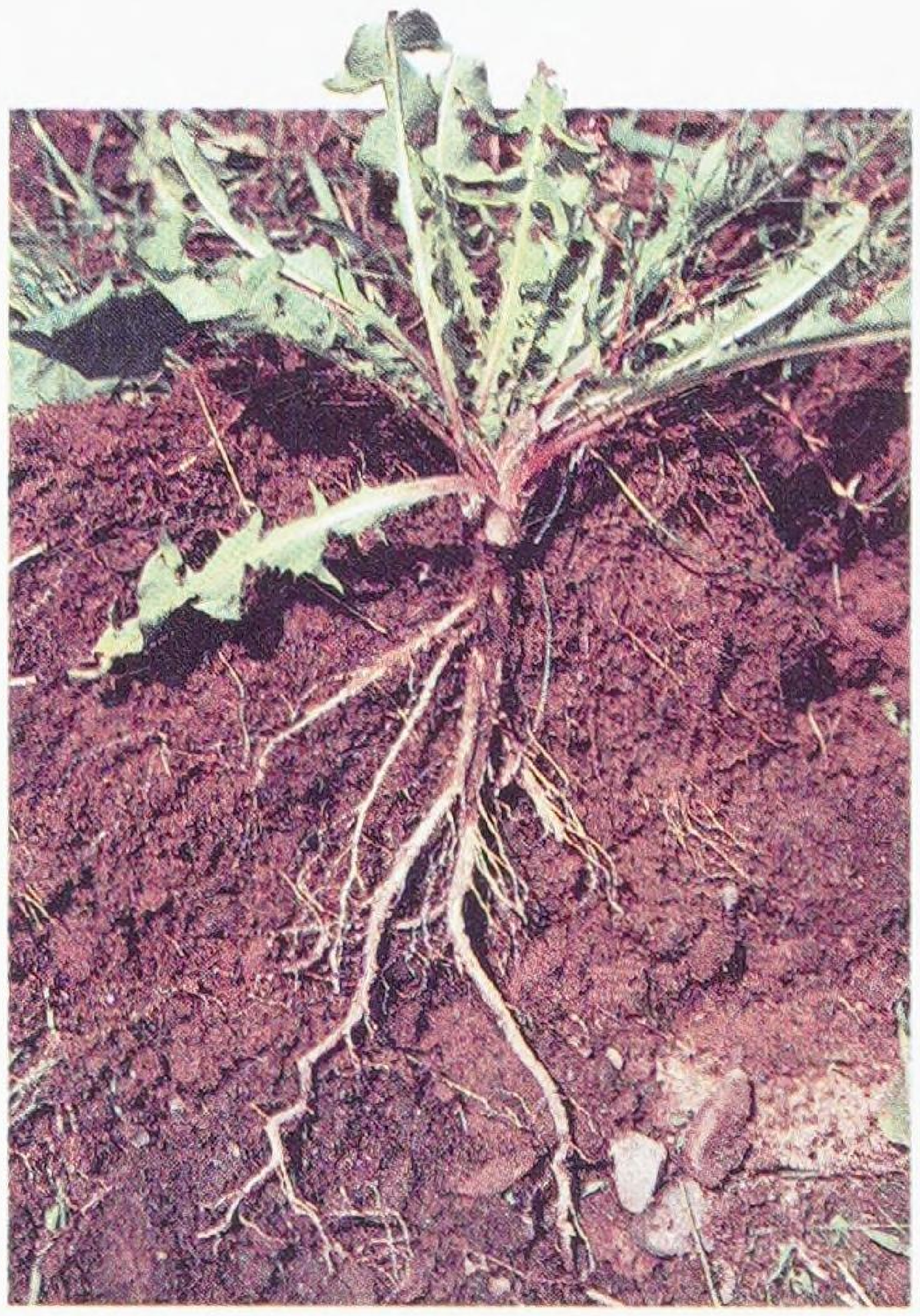


Figure 11-6. The Root System of a Dandelion

Roots also store food. When you eat carrots or beets you eat roots swollen with stored food. Root tissues may also perform special functions such as absorption of oxygen and the process of photosynthesis.

Stems

Did you know that the trunk of a tree is really its stem? The main functions of a stem are to support the aboveground parts of the plant and to allow movement of materials between leaves and roots. Some stems also have adaptations that allow them to store food. Potatoes and onions are underground stems with stored food. Sugarcane has an aboveground stem that stores large quantities of food. Stems of cacti are adapted to carry on photosynthesis and make food for the rest of the plant.

Three main tissues make up the vascular system in the roots, stems, and leaves. **Xylem** (ZI lum) tissue is made up of tubular vessels that transport water and minerals up from the roots throughout the plant. **Phloem** (FLOH em) is a plant tissue made up of tubular cells that move food from leaves and stems, where it is made, to other parts of the plant for direct use or storage. Between xylem and phloem is the cambium (KAM bee um). **Cambium** is a tissue that produces new xylem and phloem cells. All three tissues are shown in Figure 11-7.

Plant stems are either herbaceous (hur BAY shus) or woody. Herbaceous stems are soft and green. Examples are the stems of peppers, corn, and tulips.

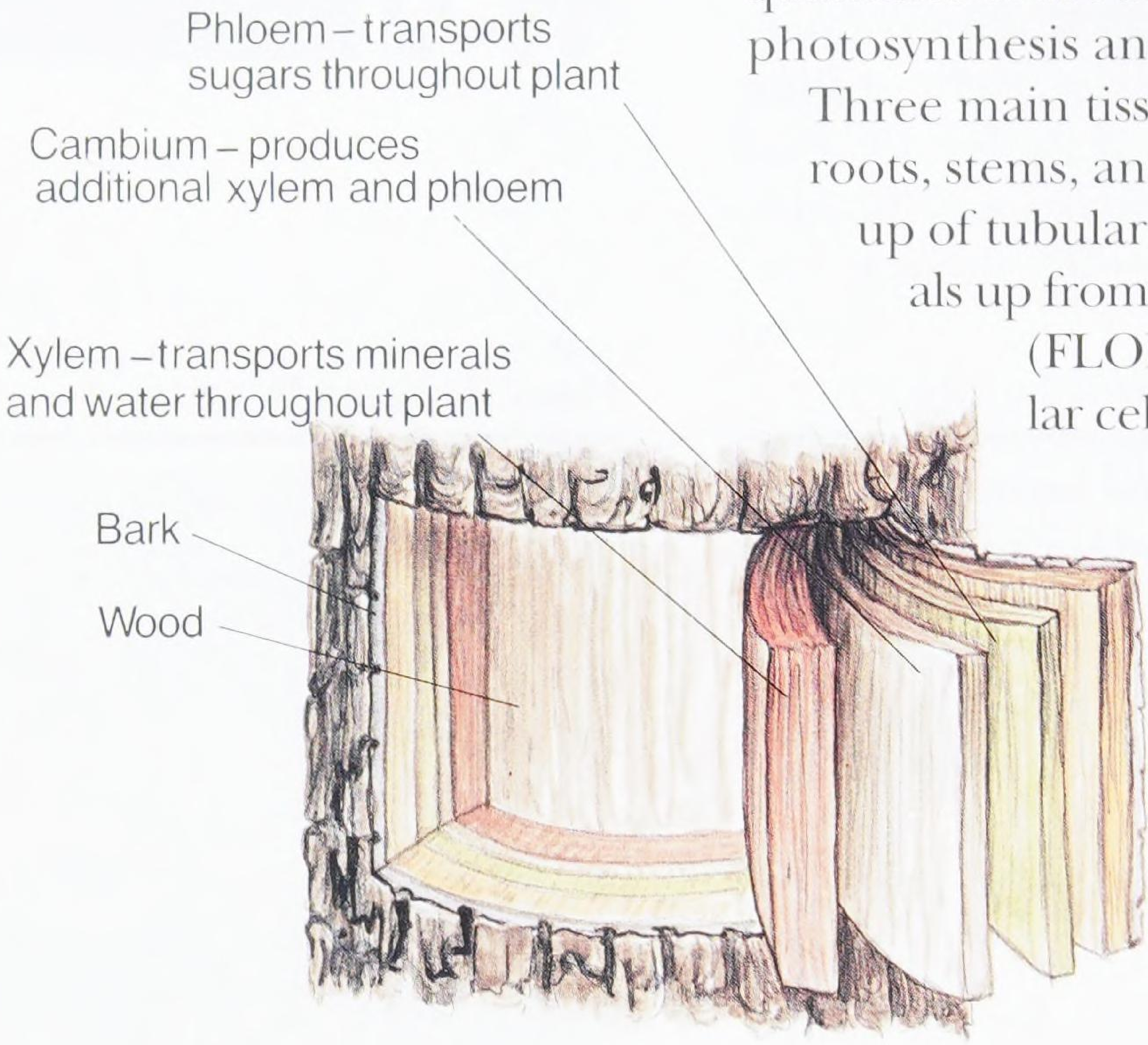

Phloem – transports sugars throughout plant
Cambium – produces additional xylem and phloem
Xylem – transports minerals and water throughout plant
Bark
Wood

Figure 11-7. The vascular tissue of seed plants includes xylem, phloem, and cambium.

TECHNOLOGY

Plants in Space?

Growing plants without soil is not new, but scientists are moving beyond traditional hydroponics, or the growing of plants in a nutrient solution.

New hydroculture techniques are being developed for use by astronauts on space missions. These techniques allow use of highly nutritious root crops. Instead of immersing roots in nutrient solutions, nutrients are sprayed directly on plant roots. This allows the plants better access to oxygen in the atmosphere, shortening growing time. The environment is carefully controlled, so the vegetables are virtually bacteria-free and pesticides are not needed. Growing trays can be tilted so less room is needed.

These techniques produce good quality vegetables without the need for farmers to worry about seasons, weather, insects, or any other environmental factors.

Think Critically: How might hydroculture be used to help the world food supply?

Oak, birch, and other trees and shrubs have woody stems. Woody stems are hard and rigid.

Leaves

Have you ever rested in the shade of a tree's leaves on a hot, summer day? Leaves are the plant organs that usually trap light and make food for the plant through the process of photosynthesis.

Look at the structure of the leaf shown in Figure 11-8. The epidermis is a thin layer of cells that covers and protects both the upper and lower surfaces of a leaf. A waxy cuticle that protects the plant from wilting or drying out covers the epidermis of many leaves. Another adaptation of leaves are small pores in the leaf surfaces called **stomata** (STOH mut uh). Stomata allow carbon dioxide, water, and oxygen to enter and leave a leaf. The stomata are surrounded by **guard cells** that open and close the pores. The cuticle, stomata, and guard cells all are adaptations that enabled plants to survive on land by conserving water.

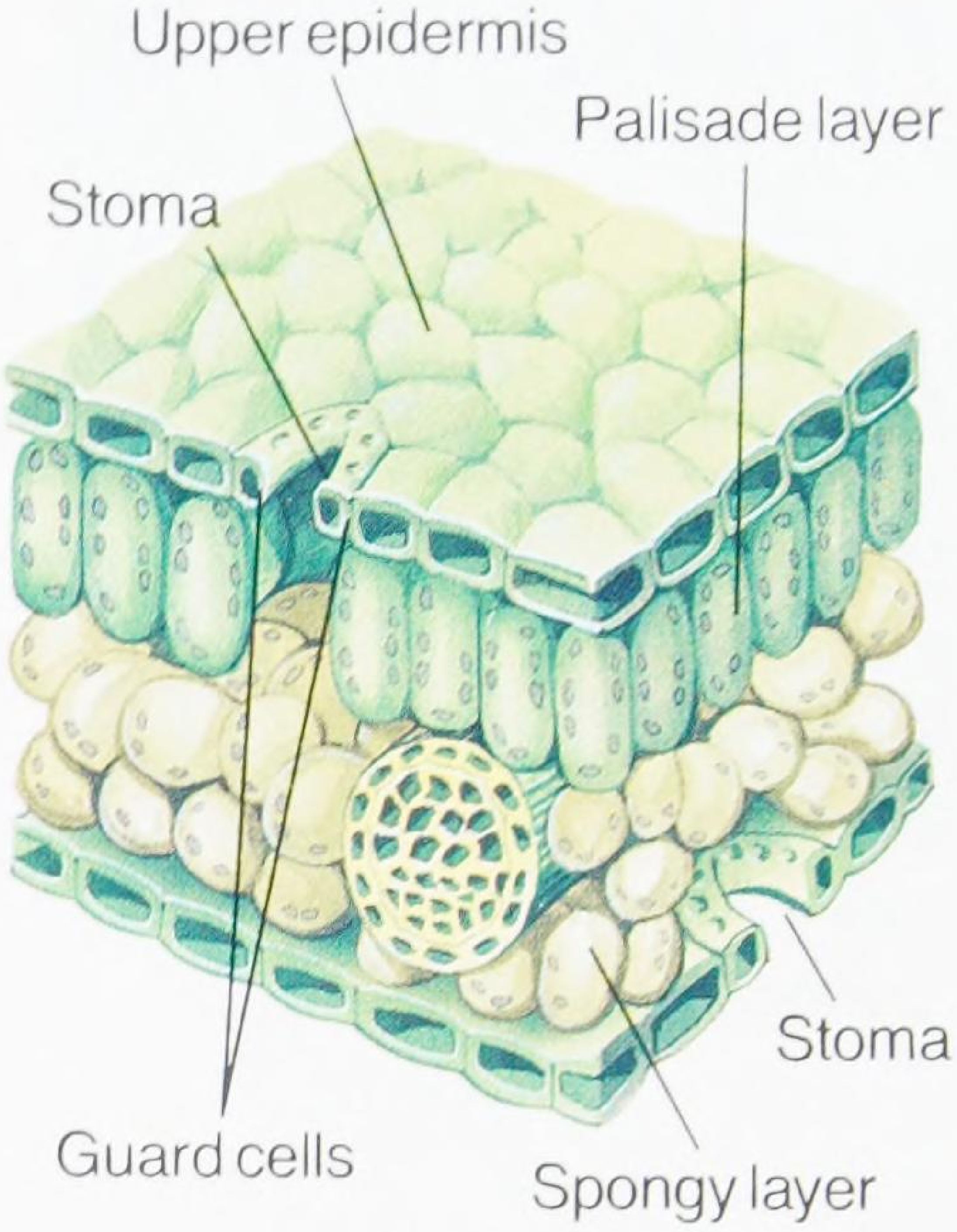


Figure 11-8. The Layers of a Leaf

Inside a typical leaf are two different types of cells. One layer, the palisade layer, has rows of closely packed cells just below the upper epidermis. Palisade cells are packed with chloroplasts filled with chlorophyll. Most of the food made by leaves is made here. Between the palisade cells and the lower epidermis is a layer of loosely arranged cells, the spongy layer, and many air spaces. Xylem and phloem vessels are located in this layer.

Where is most plant food made?

SECTION REVIEW

1. What are the functions of roots, stems, and leaves?
2. What is the advantage of having most of the chloroplasts in cells toward the top of a leaf?
3. **Apply:** The cuticle and epidermis are transparent. How is this an advantage for a plant?
4. **Connect to Physics:** Why is most of the food made in leaves produced in the layer under the upper epidermis?

Classifying

Skill Builder

From what you have learned in this section, classify the following vegetables as roots, stems, or leaves: turnip, lettuce, asparagus, potato, onion, and carrot. If you need help, refer to Classifying in the **Skill Handbook** on page 680.

11-3 Seed Plant Reproduction

New Science Words

- ovules
- pollen grains
- stamen
- pistil
- ovary
- pollination

Objectives

- Sequence the stages in the life cycles of typical gymnosperms and angiosperms.
- Describe the structure and function of the flower.
- Describe methods of seed dispersal in seed plants.

Gymnosperm Reproduction

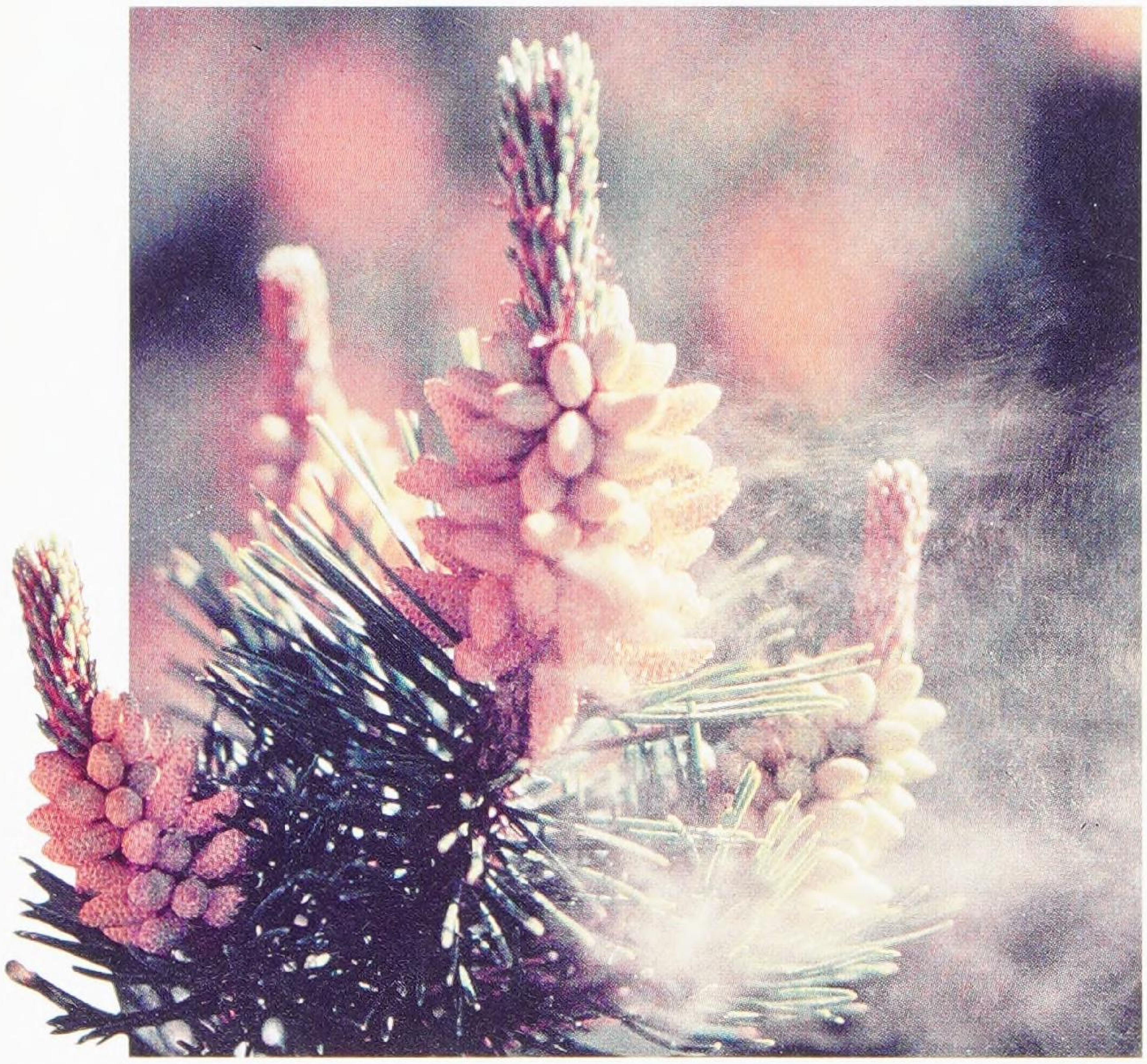


Figure 11-9. Male cones release clouds of tiny pollen grains.

Have you ever collected pine cones in the fall to use in making decorations? If you have, you've noticed that pine cones come in many different shapes and sizes. Some people can identify a pine tree just by looking at its cones.

Pine trees are typical gymnosperms. Each pine tree produces male cones and female cones on the sporophyte tree. Female cones consist of a spiral of woody scales on a short stem. Two **ovules** (OHV yewls), or eggs, are produced on top of each scale. As the ovule develops, it releases a sticky fluid. Male cones are smaller and less woody. **Pollen grains** containing the sperm, or male gametophytes, develop on the male cone. Wind carries pollen grains to the female gymnosperm cones. Millions of pollen grains may be released in a great cloud from a single male cone. You can see this in Figure 11-9. Most of this pollen never reaches the female cones because the wind blows it onto other plants, water, and the ground. When a pollen grain does get blown between the scales of a female cone of the same species, it gets caught in the sticky fluid secreted by the ovule. A **pollen tube** grows from the pollen grain to the ovule. A sperm swims down the pollen tube and fertilizes the ovule. As a result, a zygote forms. The zygote develops into a seed.

Female cones of pine trees mature, open, and release their seeds during the fall or winter months. It may take a long time for seeds to be released from a pine cone. From the moment a pollen grain falls on the female cone until the seeds are released may take as long as two years. Once seeds are released from a pine cone, they are carried away, eaten, or buried by animals. The buried seeds may germinate and eventually grow into new pine trees.

MINI-Lab

What's in a pine cone?

Using a hand lens, look at the parts that make up a gymnosperm cone. Examine the parts and draw some **in your Journal**. On a large paper towel, open the cone. Where are the seeds located? Draw some of the seeds. *Predict* how this location is an advantage for the tree species.

Angiosperm Reproduction

What is a flower?

Angiosperms all produce flowers. Flowers are important because they are the reproductive organs of angiosperms. Some flowers are not brightly colored, and many don't smell at all. Have you ever looked at the flowers of wheat, rice, or grass? Why do you think there is such variety among flowers?

The Flower

The shape, size, or color of flowers tells you something about the life of the plant. Large flowers with brightly colored petals often attract insects. In turn, these insects help to pollinate the flowers. Flowers that aren't colored often depend on wind for pollination. Their petals may be small, or the flowers may have no petals at all! Flowers that open at night often have very strong scents.

Usually the colored parts of a flower are the petals. Outside the petals are some small, leaflike parts called sepals. Sepals are easy to see when a flower is still a bud because they cover the bud. In some flowers, the sepals are as colorful as or even larger than petals.

Connect to... Physics

The scents produced by flowers are volatile compounds. Such compounds diffuse into the air as the kinetic energy of air molecules strike the scent molecules. Why would you be able to smell a group of flowers better on a windless day than a windy one?

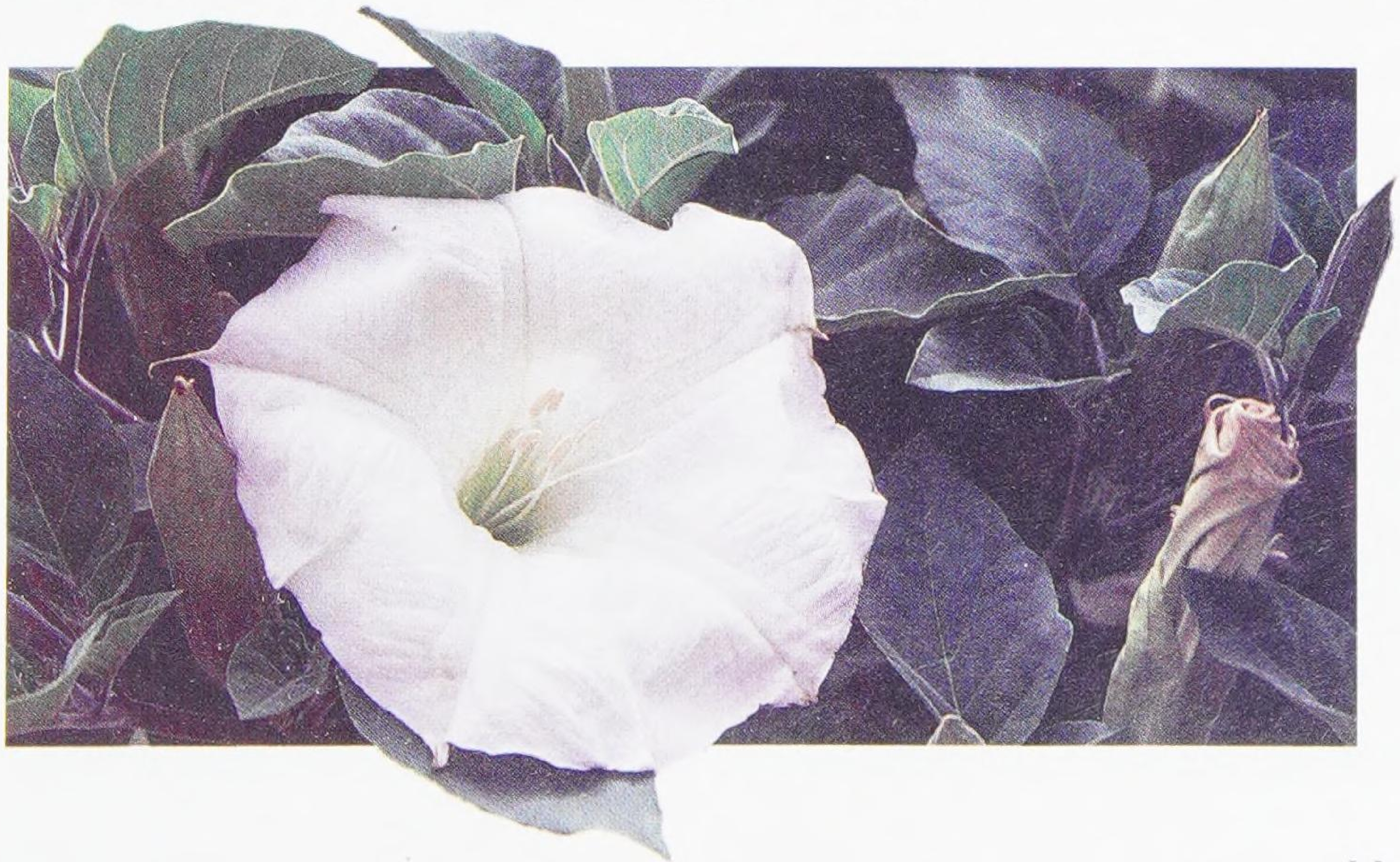


Figure 11-10. Some flowers, like the night-blooming *Datura*, depend on pollinators that are active at night.

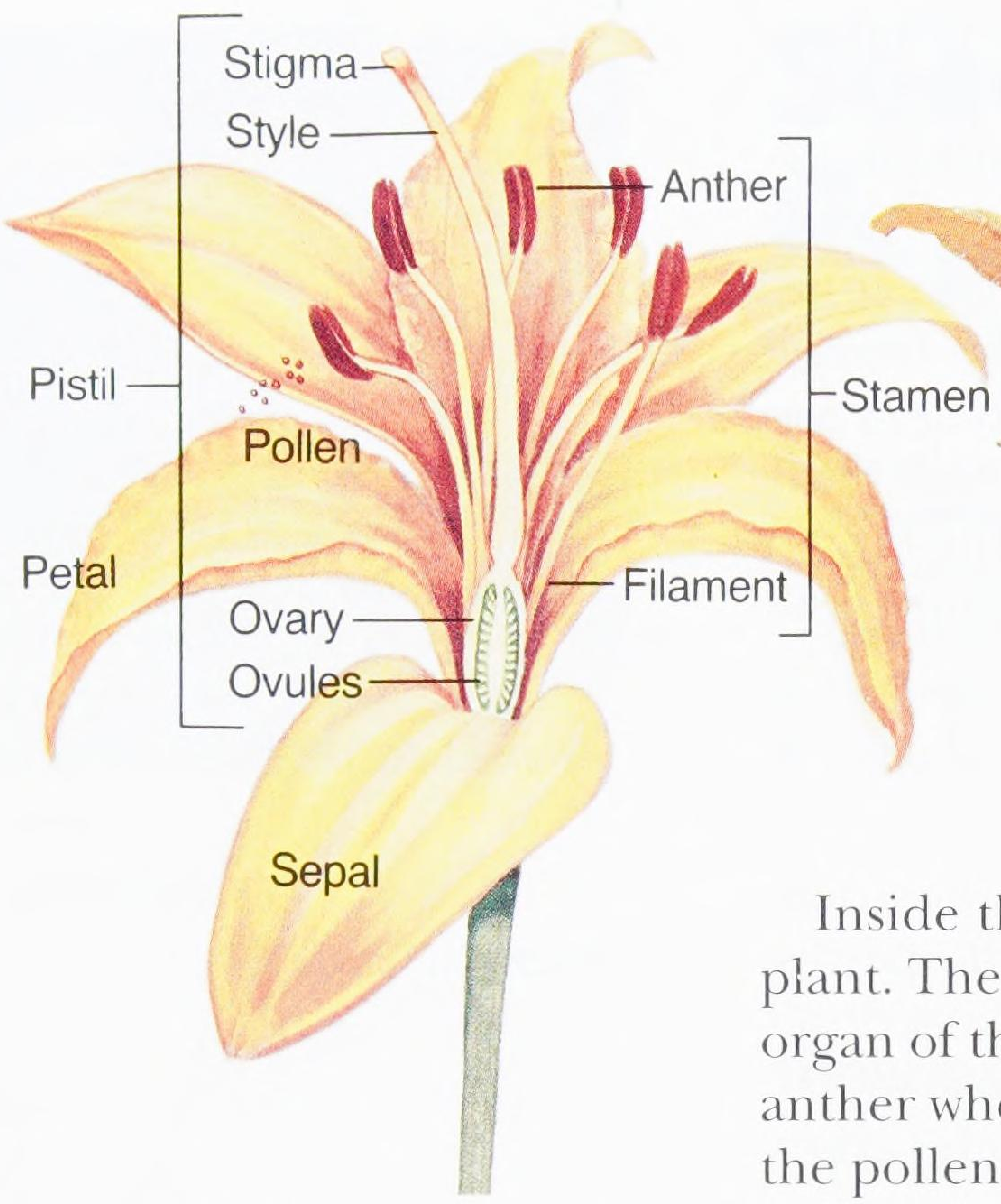


Figure 11-11. Parts of a Flower

Inside the flower are the reproductive organs of the plant. The **stamen** (STAY mun) is the male reproductive organ of the flower. Stamens consist of a filament and an anther where pollen grains form. The sperm develop in the pollen grain.

What is a pistil?

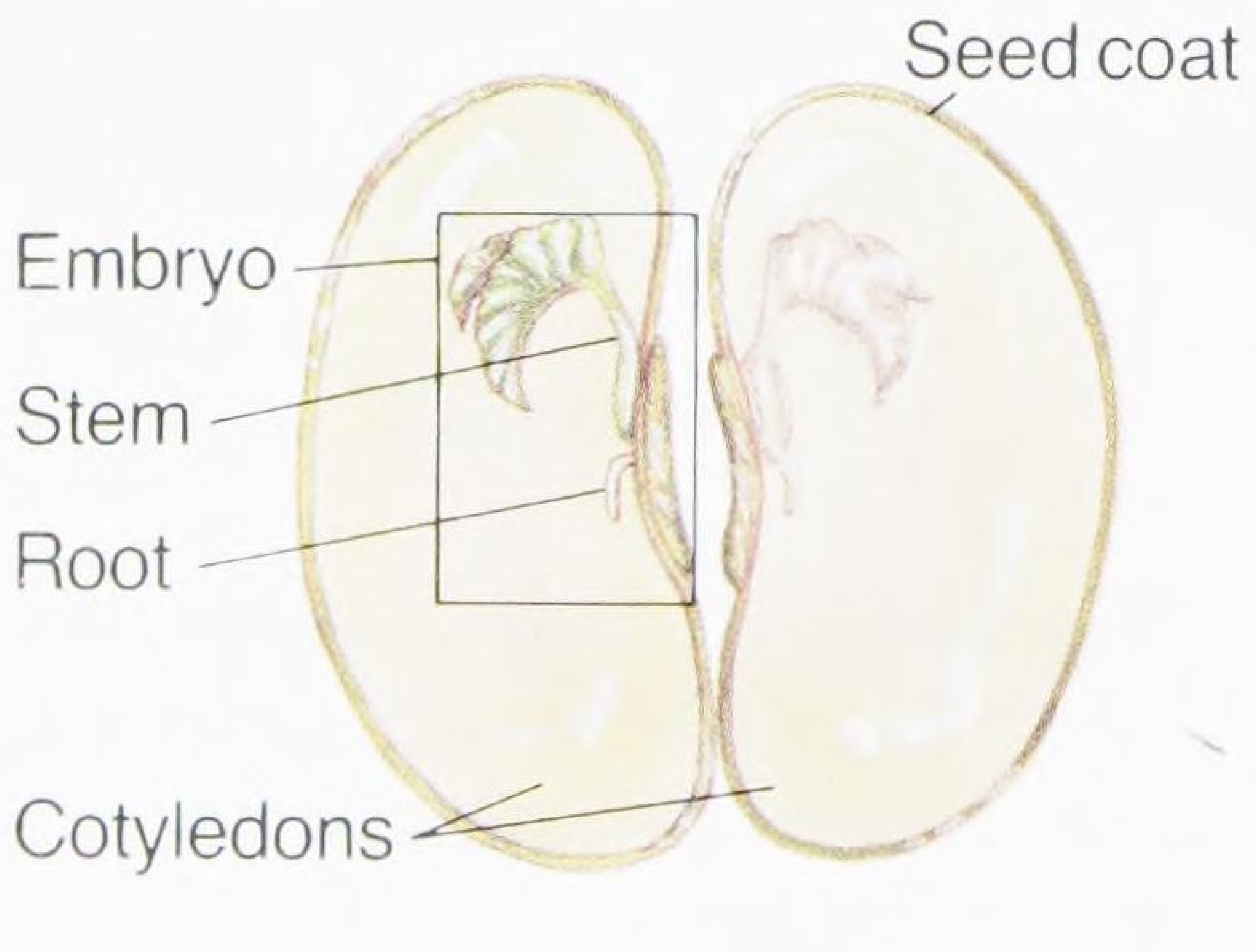
The **pistil** (PIHS tul) is the female reproductive organ of a flower. Pistils consist of a sticky stigma where the pollen grains land, a long stalklike style, and an ovary. In angiosperms, the **ovary** is the swollen base of the pistil where ovules are formed. The female gametophyte, or egg, develops in the ovule. You can see the parts of a typical flower in Figure 11-11.

Development of a Seed

How does a seed develop? Pollen grains reach the ovule in a variety of ways. Pollen is carried by the wind or by animals such as insects, birds, and mammals. A flower is pollinated when pollen grains land on the sticky stigma. The pollen tube grows from the pollen grain down through the style and into the ovary until it reaches the ovules. The sperm then travels down the pollen tube and unites with, or fertilizes, the ovule. This zygote develops into the plant embryo part of the seed. The transfer of pollen grains from the stamen to ovules is the process of **pollination.**

An embryo plant consists of cotyledons, stem, and root. Protected by a seed coat, the embryo also has a supply of stored food called the endosperm. After the embryo germinates, it will use the endosperm until it can begin to produce food on its own. You can see the parts of a seed in Figure 11-12.

Figure 11-12. The Parts of a Seed



Seed Dispersal and Germination

How do seeds get from the flower to the ground for germination? You know that the seeds grow inside the ovary. As an ovary grows larger, it becomes a fruit. Fruits may be either fleshy, like peaches or apples, or dry, like a walnut. As fruits are eaten by animals, the seeds are moved to new locations where they may be able to germinate. When you eat watermelon and spit out the seeds, you move the watermelon seeds to a new place! Both dry and fleshy fruits protect the seeds. Some seeds cannot germinate until the fruit has been digested by an animal, and the seeds are released in the animal's feces. Seeds are also dispersed by the wind or water or carried along on fur or clothing.

MINI-Lab

How do plants disperse seeds?

Look at the seeds pictured in Figure 11-13. How are the seeds of each plant dispersed—by wind, water, insects, birds, or mammals? *Identify* features that tell you how each is dispersed?

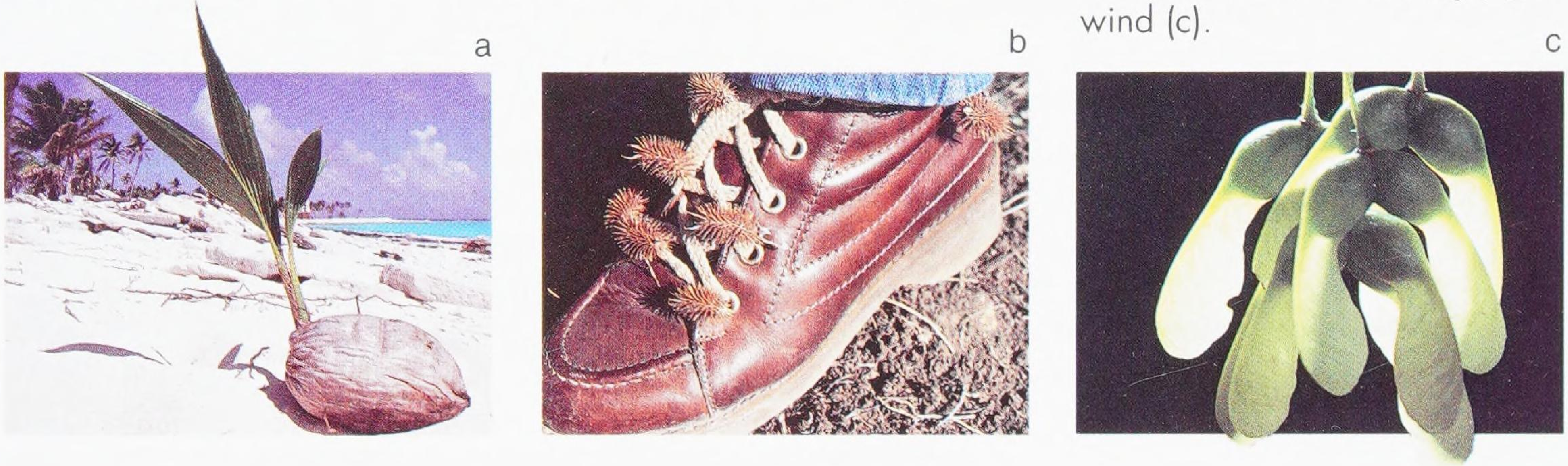


Figure 11-13. Seeds can be dispersed by floating (a); attaching to fur, feathers, or clothing (b); or wind (c).

PROBLEM SOLVING

How Can You Tell If Seeds Are Living?

Aurora visited her grandfather, who lived in a nursing home. They went to buy flower seeds to plant in the courtyard of the nursing home. When examining a package of petunia seeds, Aurora noticed that the package said the seeds were 95 percent viable. Her grandfather explained that *viable* meant living. He said that 95 out of 100 seeds would germinate and grow.

They purchased the petunia seeds and several other packages of flower seeds and headed back to the nursing home to plant them. How could Aurora and her grandfather determine if the seeds they planted in the courtyard were viable?

Think Critically: How could Aurora determine if the seed company's claim on the seed package were true?

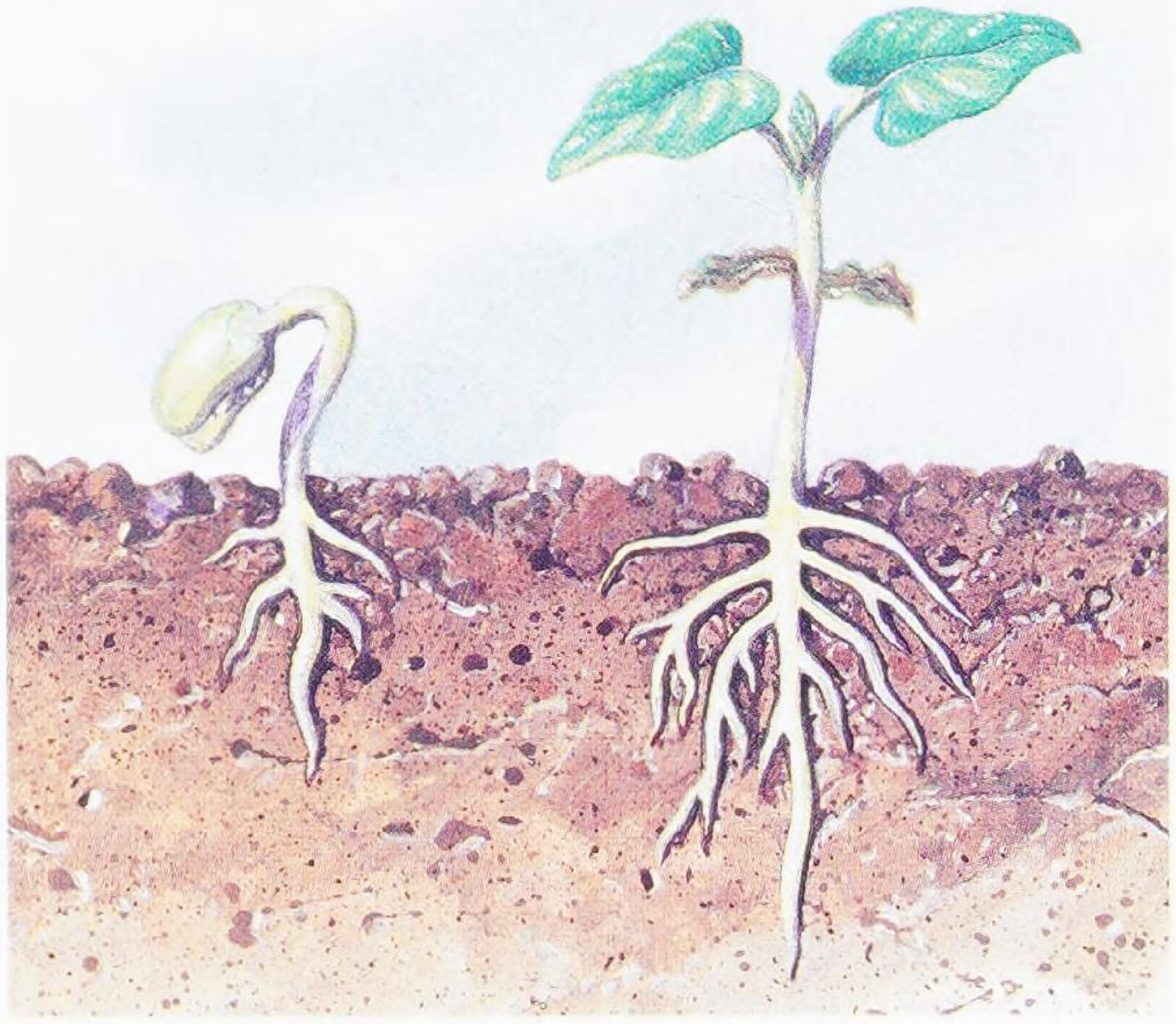


Figure 11-14. In dicots, the cotyledons raise the seed above the soil. As the endosperm is used the cotyledons shrivel and fall off.

What is germination?

When a seed reaches the soil, it may not germinate right away. Seeds often remain dormant until conditions are right for germination. Some seeds can remain dormant for hundreds of years, yet still be able to grow when environmental conditions become favorable. In 1982 seeds of the East Indian lotus germinated after 466 years!

Germination, or the development of a seed into a new plant, begins when water is taken into the seed tissues. Water signals the seed to begin growth. The endosperm provides the energy for the seed to grow. Usually the root begins to elongate and grow out of the seed first. Then the stem lifts the cotyledons above the soil. If the seed is a monocot, the seed containing the endosperm remains below the soil. In a dicot seed, such as a bean, the cotyledons contain most of the endosperm of the seed.They also raise the seed above the surface. Eventually, as the food is used, the cotyledons shrivel and fall off dicot plants. Then the plant takes over and makes all of its own food by photosynthesis.

SECTION REVIEW

1. Compare life cycles of angiosperms and gymnosperms.
2. Diagram the parts of a flower and label their functions.
3. List three methods of seed dispersal in plants.
4. **Apply:** Some conifers bear female cones on the top half of the tree and male cones on the bottom half. What do you think this arrangement of male and female cones on trees helps to prevent or promote?
5. **Connect to Physics:** A watered seed will soon germinate. What force enables the seedling to push up through soil?

Skill Builder

Hypothesizing

A corn plant produces thousands of pollen grains on top of the plant in flowers that have no odor or color. The pistils grow from the cob lower down on the plant. Explain how a corn plant is probably pollinated. If you need help, refer to Hypothesizing in the **Skill Handbook** on page 686.

ACTIVITY 11-1

Inside a Seed

Problem: *What can you see inside a seed?*

Materials

- soaked lima bean
- soaked seed corn
- forceps
- scalpel
- iodine solution
- hand lens

Procedure

1. Make a data table in your Journal.
2. Examine the soaked corn seed. Place the seed flat on the table and, using a scalpel, cut through the center of the light-colored area on the front of the seed. **CAUTION:** *Always be careful when handling a scalpel.*
3. **Hypothesize** which part or parts contain starch for food. Place a drop of iodine solution on different parts of the seed to test for starch. A blue-black color indicates the presence of starch. **CAUTION:** *Iodine is poisonous and may stain and burn the skin.*
4. Locate and *observe* the embryo corn plant with its single cotyledon. Find the embryo stem and the embryo root. Draw and label the seed in your Journal.
5. Using the hand lens, *observe* the lima bean.
6. Locate the two thick cotyledons and the embryo plant. Separate the cotyledons. Draw and label the seed in your Journal.
7. Test the lima bean for starch. Which part or parts contain starch?

Data and Observations

	Number of Leaves	Size of Endosperm
Monocot		
Dicot		

Analyze

1. What is the function of the outer covering of the seed?
2. Which parts tested positive for starch?
3. What is the function of the endosperm?
4. What parts are found in both monocot and dicot seeds?

Conclude and Apply

5. Which seed had the larger cotyledon? Is there an adaptive advantage for a seed to have a larger cotyledon? Explain.
6. How can you tell the difference between a monocot and a dicot by dissecting the seed?
7. **Design an experiment** to show which parts of the embryo become roots, stems, or leaves.

SCIENCE & SOCIETY

11-4 Effects of Acid Rain

New Science Words

acid rain

Objectives

- State the primary causes of acid rain.
- Explain why the solution to this problem requires international cooperation.

Acid Rain: An International Problem

Suppose you and your friends go on a camping trip. As you are walking into the forest you are shocked by the death around you. The trees are brown. There are no plants on the forest floor. You can hear no birds or animals. You go fishing in a small lake, but there are no fish there to catch.

It is hypothesized that during the 1980s, southeastern Canada, northeastern and northwestern United States, and much of Europe began to experience the effects of acid rain. **Acid rain** is precipitation that falls to Earth after combining with sulfur dioxide and nitrogen oxide in the air. Sulfur dioxide and nitrogen oxide are gases released when fossil fuels such as coal and oil are burned. Sulfur dioxide typically enters the air in emissions from coal-burning power plants, whereas nitrogen oxide is released in the exhuast of automobiles. In the air, sulfur dioxide and nitrogen oxide combine with water vapor to form sulfuric acid and nitric acid. When it rains, snows, or fog covers the ground, these acids land on water or soil. Acid rain is particularly harmful to organisms that live in water.

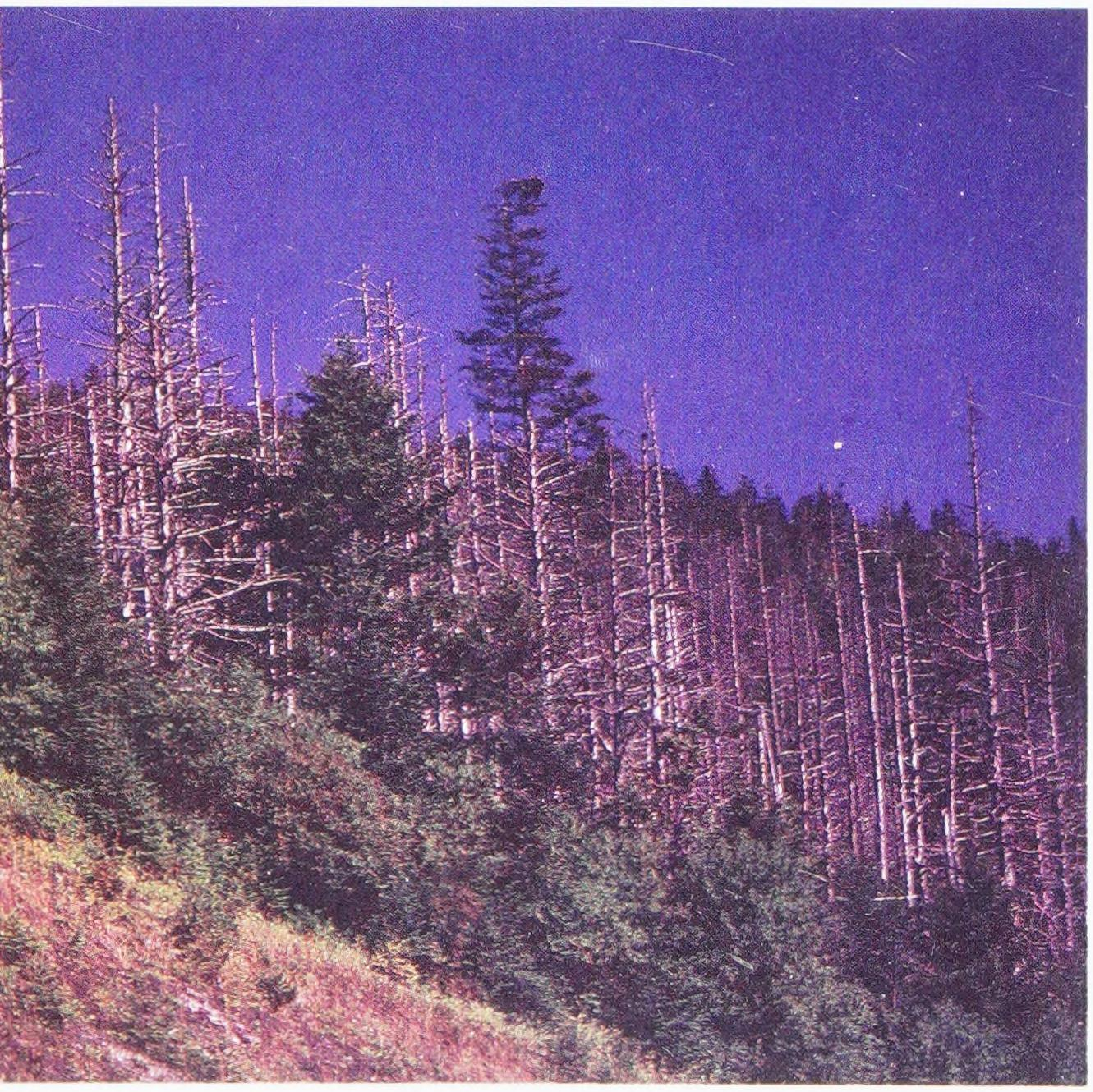


Figure 11-15. Forests affected by acid rain often die from the top down.

Hundreds of thousands of lakes in the United States and Canada have been damaged due to acid rain. Forests, buildings, outdoor artwork, and groundwater are also affected by this problem. It is thought that the decline in maple syrup production in the United States and Canada over the last ten years may be due to acid rain. Many forests in Europe are badly damaged. Acid rain causes the chemistry of the soil to change. Some minerals such as calcium and iron are washed away, while unusual amounts of other minerals such as aluminum are released from the soil and taken up by plants.

Much of the acid rain that falls in the eastern parts of the United States and Canada was produced in the Midwest. Scientists in Canada and the United States are working together to try and solve this vast problem. In some parts of Canada, up to 75 percent of the acid rain is due to pollution from the United States. Most of the emissions that result in acid rain in the United States originated here. Studies show that by decreasing the amount of these chemicals released into the air, the damage they cause can be greatly decreased. Many industries in the United States and Canada use scrubbers to remove some of these chemicals. A scrubber is a machine that blows a fine mist of water through gases leaving a power plant's smokestacks. Sulfur dioxide and nitrogen oxide combine with the water in the mist instead of water vapor in the air. The scrubbers are very expensive, yet they prevent much of the sulfur dioxide and nitrogen oxide from being released.

Other means of reducing the emission of the chemicals that cause acid rain are also being developed. It is hoped that each country will develop its own acid rain control program to allow all countries to benefit from an undamaged environment.

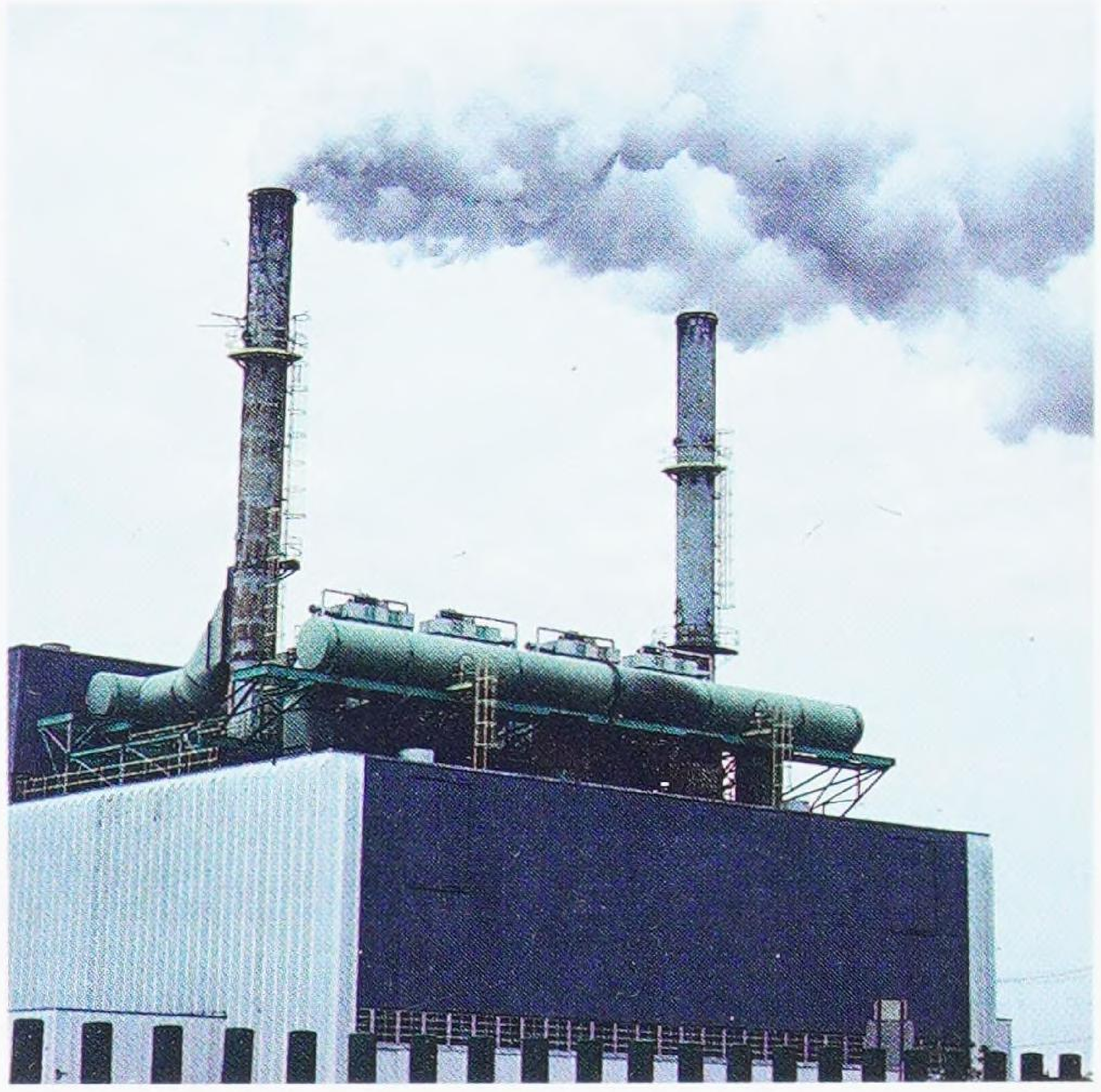


Figure 11-16. Installing scrubbers in smokestacks can reduce emissions that result in acid rain.

Connect to...

Earth Science

Acid rain is carried from its sources by winds. Because of this, acid rain is a global problem. Find out what trade winds, prevailing westerlies, polar easterlies, and jet streams are.

SECTION REVIEW

1. What chemicals are responsible for acid rain?
2. **Connect to Earth Science:** Why is acid rain an international issue?

You Decide!

SCIENCE & SOCIETY

Some people believe the damaging effects of acid rain are not important enough to discontinue the use of coal and other fossil fuels. Others feel that the use of fossil fuels should be minimized unless expensive scrubbers are used. How do you think the problem should be solved?

ACTIVITY 11-2

Parts of a Flower

Problem: *What are the parts of a flower?*

Materials

- gladiolus flower
- scalpel
- hand lens
- black paper
- microscope
- microscope slide
- coverslip
- dropper
- water

Procedure

1. Make a data table like the one shown in your Journal.
2. Examine a gladiolus flower. Remove the outer row of colored leaflike parts called the sepals. Use Figure 11-11 on page 264 to *identify* common flower parts. Record the number and color of sepals in your data table.
3. The leaflike structures inside the sepals are the petals. Remove the petals and record their number and color.
4. Locate the stamens and remove them. Look at one of the stamens with a hand lens. Observe the top part, called the anther, and the stalk, called the filament. Record the number and color of stamens in your table.
5. Tap the anther on black paper to knock out the pollen grains. Observe under a microscope. Draw what you see in your Journal.
6. The structure that remains is the pistil. Identify the three parts. The three-part stigma is at the top. The stalklike part is the style. The ovary is the swollen base of the pistil. *Record* the number and color of pistils.
7. Use a scalpel to *make a cross section* of the ovary. **CAUTION:** *Always be careful with sharp instruments.* Use a hand lens to look at the ovules inside the ovary. Make a drawing in your table.

Data and Observations

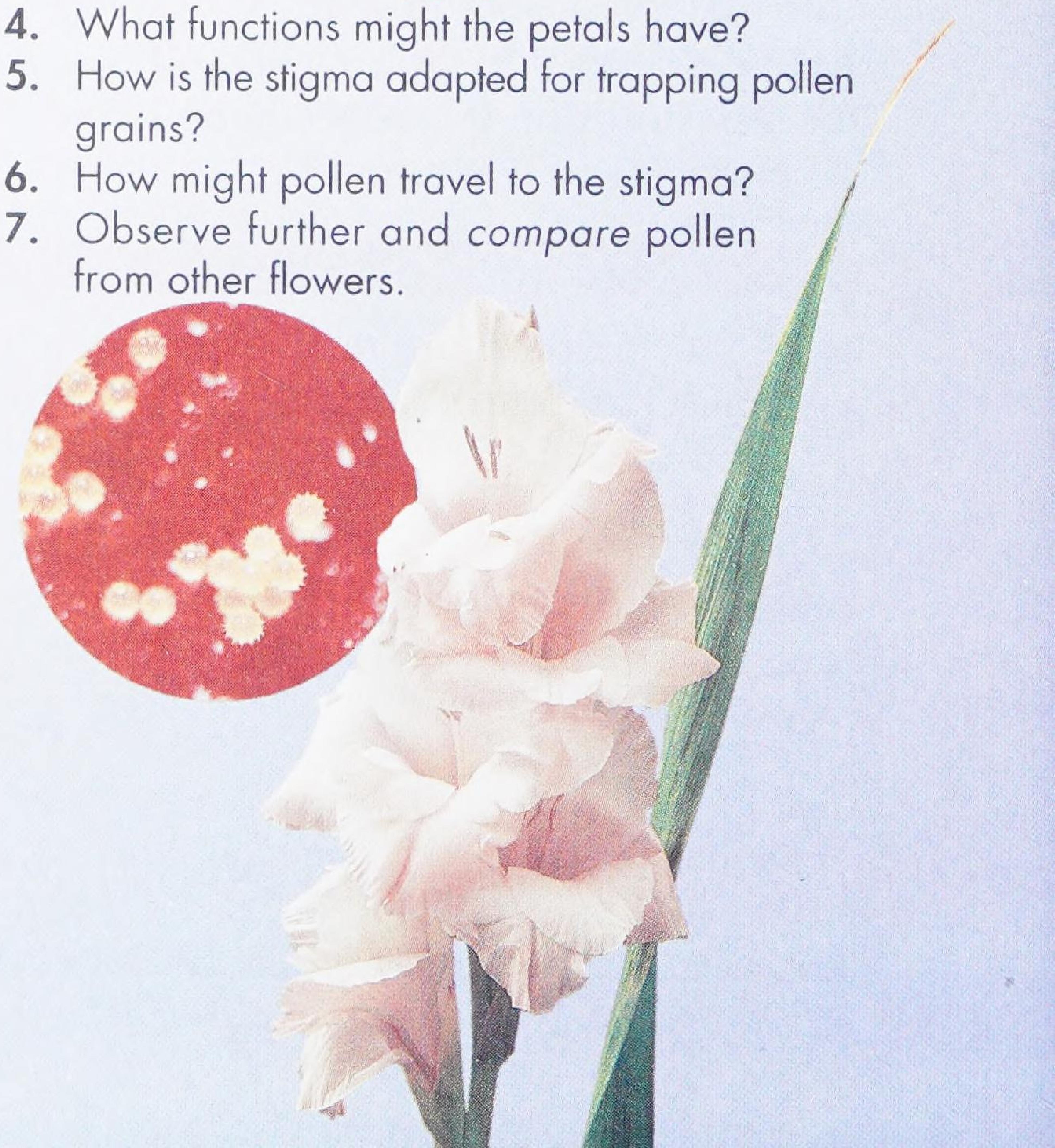
<table>
<tr><th>Flower Part</th><th>Number</th><th>Color</th></tr>
<tr><td>Sepals</td><td></td><td></td></tr>
<tr><td>Petals</td><td></td><td></td></tr>
<tr><td>Stamens</td><td></td><td></td></tr>
<tr><td>Pistils</td><td></td><td></td></tr>
<tr><th colspan="2">Pollen Grains</th><th>Ovules</th></tr>
<tr><td colspan="2"></td><td></td></tr>
</table>

Analyze

1. How do the numbers of stamens, petals, and sepals compare?
2. Describe the appearance of the stigma.
3. How many compartments are in the cross section of the ovary?

Conclude and Apply

4. What functions might the petals have?
5. How is the stigma adapted for trapping pollen grains?
6. How might pollen travel to the stigma?
7. Observe further and *compare* pollen from other flowers.



CHAPTER REVIEW

SUMMARY

11-1: Seed Plants

1. Seed plants have stems, roots, and leaves, and grow from seeds.

2. Gymnosperms produce seeds on cones; angiosperms produce seeds in flowers.

3. Seed plants are sources of oxygen, food, clothing, furniture, and other products.

11-2: Parts of Complex Plants

1. Roots absorb water and minerals, store food, and anchor the plant.

2. Stems transport food and water between roots and leaves and support the plant.

3. The palisade layer of leaves carries out photosynthesis. Xylem and phloem tissues are located in the spongy layer of the leaf.

11-3: Seed Plant Reproduction

1. Wind carries gymnosperm pollen to female cones where fertilization occurs.

2. In angiosperms, pollen reaches the stigma and travels to the ovary to fertilize the ovules.

3. Flowers contain male and female structures. The female pistils consist of the stigma, style, ovary, and ovules. The male stamens consist of the filament and anther, where pollen grains are formed.

11-4: Science and Society: Effects of Acid Rain

1. Acid rain results when sulfur dioxide and nitrogen oxide combine with water vapor in the air to form sulfuric acid and nitric acid.

2. Most acid rain results from emissions from the burning of fossil fuels such as coal and oil.

3. Acid rain may travel far from its source and cause problems in other states or countries. International cooperation is needed to solve this problem.

KEY SCIENCE WORDS

a. **acid rain**
b. **angiosperms**
c. **cambium**
d. **dicots**
e. **guard cells**
f. **gymnosperms**
g. **monocots**
h. **ovary**
i. **ovules**
j. **phloem**
k. **pistil**
l. **pollen grains**
m. **pollination**
n. **stamen**
o. **stomata**
p. **xylem**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. transfer of pollen grains to ovules
2. cone-bearing plants
3. male part of a flower
4. small pores in leaf surfaces
5. water containing sulfur dioxide
6. flower-producing plants
7. female part of a flower
8. vessels that transport water and minerals
9. plants with one embryo leaf
10. moves food from leaves and stems

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. Gymnosperms include _______.
   a. oaks c. gladiolus
   b. flowers d. pines
2. Angiosperms produce _______.
   a. cones c. needles
   b. flowers d. woody scales
3. Colorful flowers are usually pollinated by_______.
   a. insects c. clothing
   b. wind d. birds
4. A _______ is the sticky part of a flower.
   a. sepal c. stamen
   b. ovary d. stigma
5. The _______ contains food for the embryo.
   a. endosperm c. stigma
   b. pollen grain d. root
6. The seed leaves of an embryo are _______.
   a. root hairs c. guard cells
   b. cotyledons d. stomata
7. _______ anchor plants in soil.
   a. Leaves c. Stomata
   b. Stems d. Roots
8. _______ produces new xylem and phloem.
   a. Epidermis c. Pollen
   b. Cambium d. An ovule
9. Most photosynthesis occurs in the _______.
   a. guard cells c. epidermis
   b. packed layer d. cuticle
10. A _______ provides waxy protection for the leaf.
    a. guard cell c. cuticle
    b. epidermis d. loose layer

USING LAB SKILLS

11. In the Find Out! on page 253, you looked at the parts of a peanut seed. Now that you know about the different parts of a seed, draw and label the embryo, stem, roots, and endosperm of the peanut.
12. **Design an experiment** to test the viability of bean seeds as in the Problem Solving on page 265. Carry out your experiment. What percentage of viability did you find? How could you increase the accuracy of the result?

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. What adaptations of flowers help pollination?
14. Both petals and sepals of the gladiolus flower are brightly colored rather than just green. Make a hypothesis about why natural selection might have favored colored petals and sepals over plain green ones.
15. What prevents water loss in leaves?

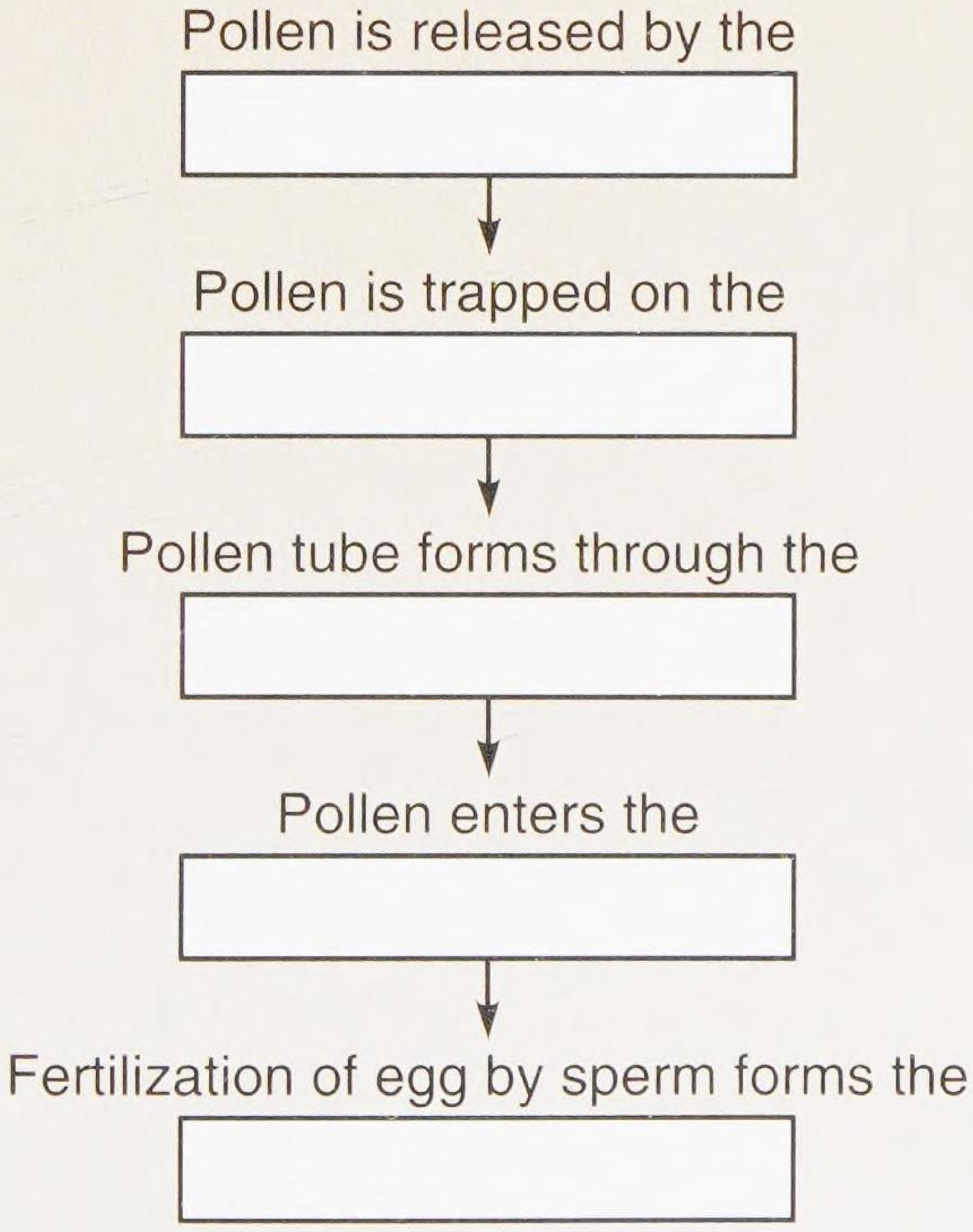
APPLY

16. What function does resin serve for the gymnosperm that secretes it?
17. Plants called succulents store large amounts of water in their leaves. In what kind of environment would you find succulents?
18. Why would cacti benefit from thick cuticles?
19. Use an example to describe a flower that is pollinated by insects.
20. Classify each fruit as dry or fleshy: acorn, almond, apple, cherry, orange, peanut.

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Comparing and Contrasting:** Compare the functions of roots, stems, leaves, and seeds in seed plants.
2. **Comparing and Contrasting:** Compare and contrast these structures of monocots and dicots: number of seed leaves, bundles arranged in stems, veins in leaves, flower parts.
3. **Concept Mapping:** Fill in the following concept map to show the sequence of pollination and fertilization.


Pollen is released by the
Pollen is trapped on the
Pollen tube forms through the
Pollen enters the
Fertilization of egg by sperm forms the

4. **Interpreting Data:** Interpret the data in the table below concerning stomata of these leaf types. What do these data tell you about where gas exchange occurs in each type?

Stomata (per mm^2)	Upper Surface	Lower Surface
Pine	50	71
Bean	40	281
Fir	0	228
Tomato	12	13

5. **Observing and Inferring:** Observe pictures or specimens of flowers and infer how each is pollinated. What features does each flower have to enable the pollination you suggest?

PROJECTS

1. Identify the types of trees in your yard or at your school. You can collect leaves and press them between papers placed inside a phone book. Identify leaves by using a guide book from the library. Bring your collection to school.
2. Research how hydroponics is used to grow plants. Using this technique, try to grow a plant.

CHAPTER

12 Plant Processes

Have you ever forgotten to water a potted plant? What happened to the plant after awhile?

FIND OUT!

Do the following activity to find out how water enters and leaves a plant.

Obtain a resealable plastic bag and a small potted plant from your teacher. Water the plant, then cover the plant and its pot with the plastic bag. Seal the bag. Place the bag in a sunny window and observe. What collects on the inside of the bag? Where does this substance come from? Some materials move in and out of leaves through tiny openings on leaf surfaces. Carbon dioxide is one of the substances that enters leaves through these openings. If enough water is lost by a plant and not replaced, what do you *predict* will happen to the plant?

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 12-1 Photosynthesis and Respiration
- Gas Exchange
- Photosynthesis
- Respiration

Section 12-2 Plant Responses
- What Are Plant Responses?
- Plant Responses and Plant Hormones
- Photoperiods

Section 12-3 Plant Relationships
- Parasitic Relationships
- Mutual Relationships
- Coevolution

Section 12-4 Science and Society The Treasure of Tropical Plants
- Medical Miracles from the Tropics

Previewing Science Skills

- In the **Skill Builders,** you will compare and contrast and hypothesize.
- In the **Activities,** you will observe, compare, interpret data, and make and use tables.
- In the **MINI-Labs,** you will relate, experiment, and compare.

What's next?

In this chapter you will learn about the process of photosynthesis, how plants respond to changes in chemicals, light, and gravity. You will also learn about the relationship of plants to other living things.

12-1 Photosynthesis and Respiration

New Science Words

transpiration
photosynthesis
respiration

Objectives

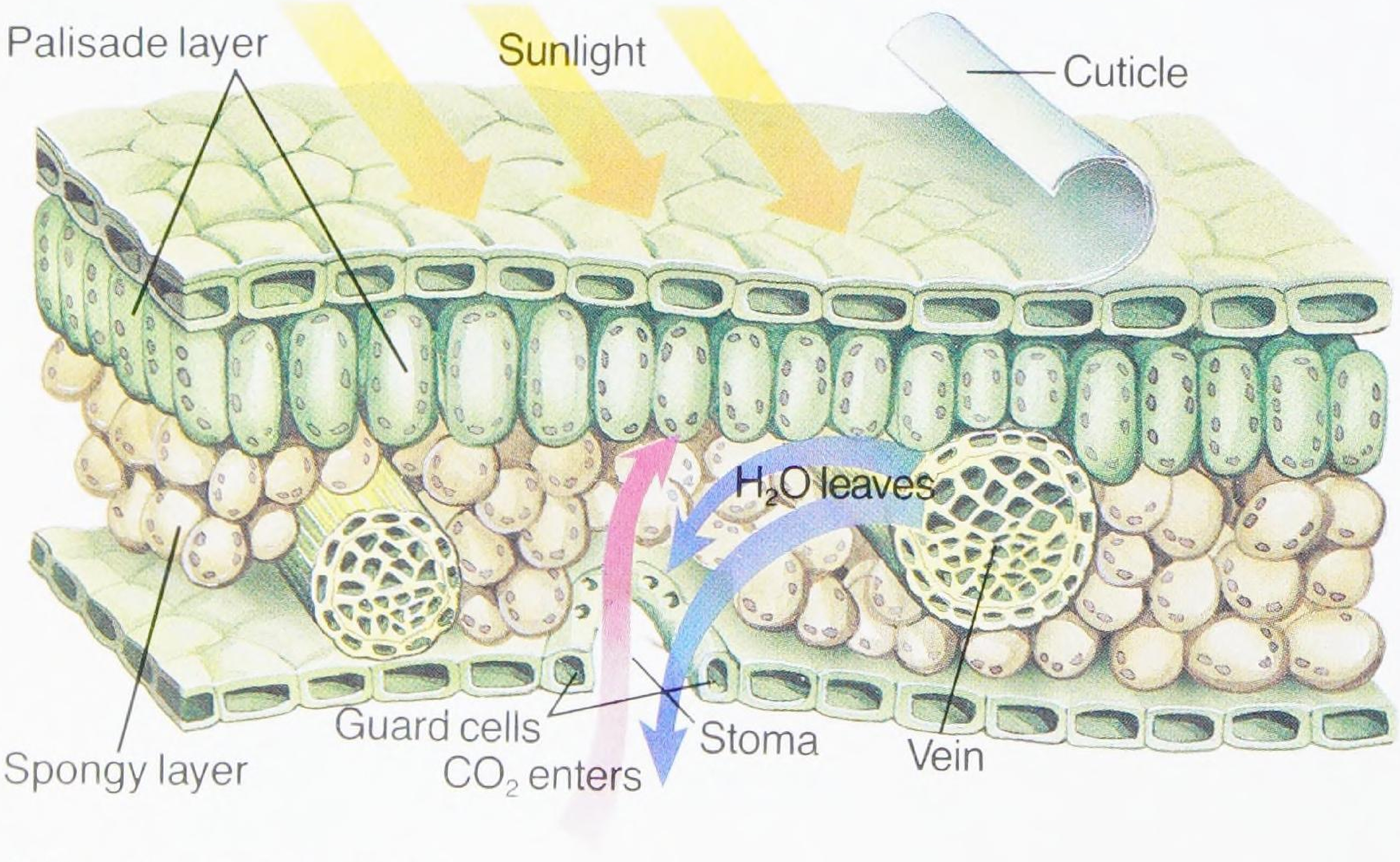
- Describe the process of gas exchange in plants.
- Explain the process and importance of photosynthesis.
- Describe the process and importance of respiration and its relationship to photosynthesis.

Gas Exchange

When you breathe in, your lungs take in a mixture of gases called air. Air is made up of nitrogen, oxygen, and a small amount of carbon dioxide. On exhaling, you release a mixture of gases, now with slightly more carbon dioxide. Gas exchange is one of the ways living cells obtain raw materials and get rid of waste products.

Plants need water and carbon dioxide to survive. Plants absorb water and minerals through their roots. Water travels up from the roots through the stem to the leaves. Water evaporates from leaf tissues and is released through stomata as water vapor. Carbon dioxide, a gas, gets into plants through stomata on leaf surfaces. Because leaves usually have more stomata on the lower surface, more carbon dioxide enters the spaces of the spongy layer, as shown in Figure 12-1. Water vapor is also found in the air spaces of the spongy layer. Carbon dioxide and water vapor are exchanged by diffusion through the stomata on leaf surfaces.

Figure 12-1. Carbon dioxide is taken into leaves through stomata. Water vapor is lost to the air when stomata open.



How does carbon dioxide enter a leaf? Each

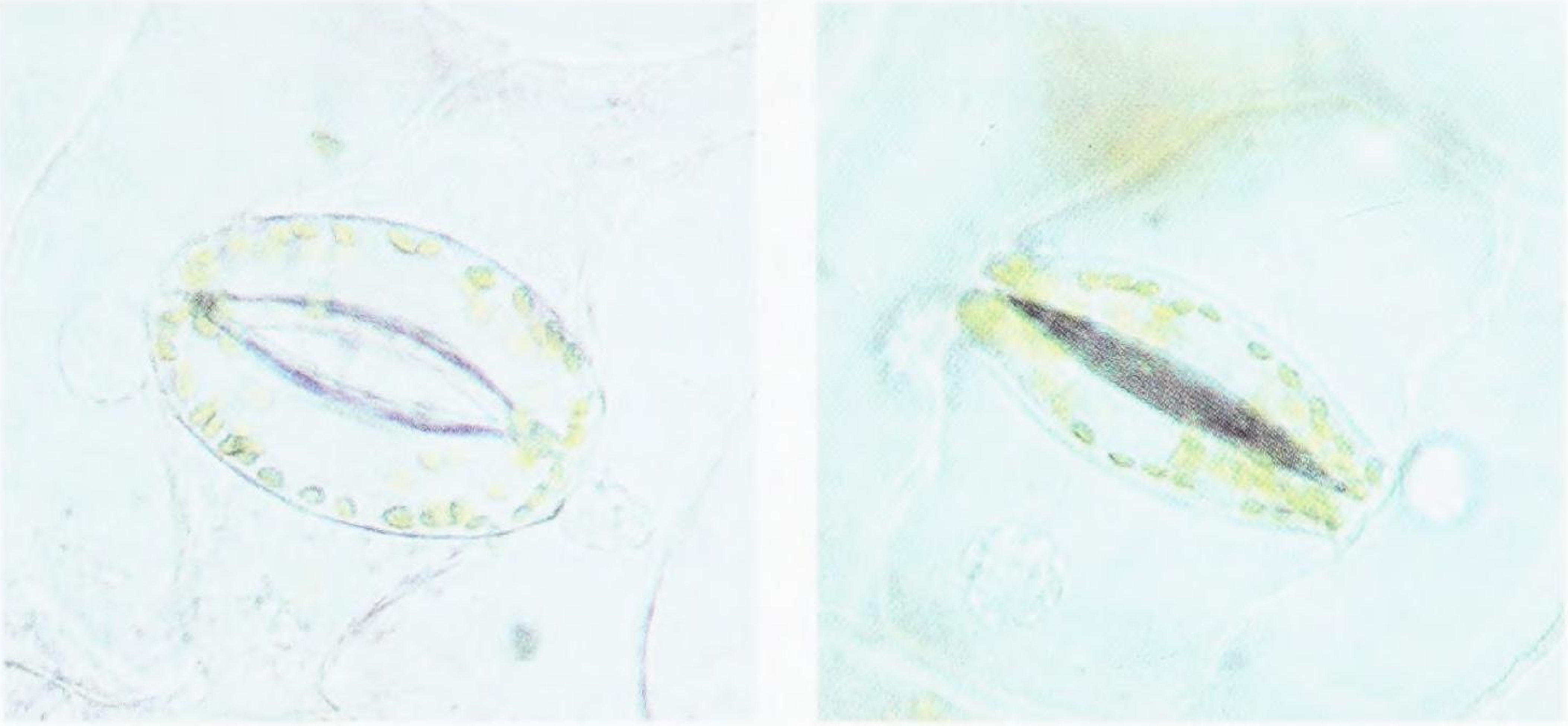


Figure 12-2. Stomata open when guard cells absorb water and close when water is lost.

stoma is surrounded by two guard cells that control the size of the opening. Water moves into and out of guard cells by osmosis. When guard cells absorb water, they swell and the stoma opens, letting carbon dioxide in. Water vapor escapes during the process. When guard cells lose water, they relax and the stoma closes. Figure 12-2 shows open and closed stomata.

Light, water, and carbon dioxide all affect the opening and closing of stomata. Stomata usually are open during the day when photosynthesis is going on. When photosynthesis stops at night, the stomata are usually closed. Less carbon dioxide enters and less water vapor escapes from the leaf when stomata are closed.

If you did the Find Out activity on page 275, you saw that water vapor condensed on the inside of the plastic bag. Loss of water vapor through stomata of a leaf is called **transpiration.** Far more water is lost through transpiration than is used during photosynthesis.

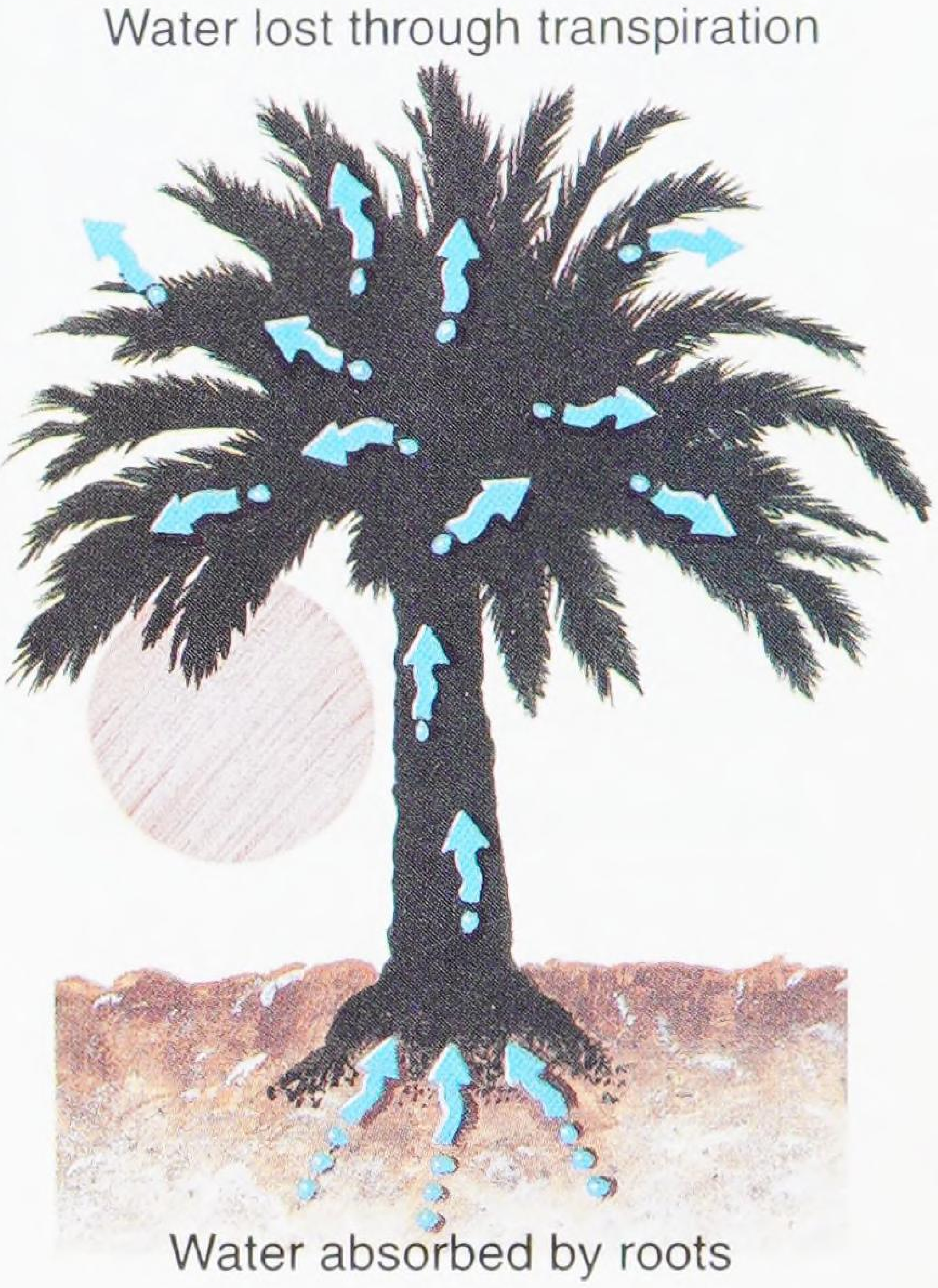


Figure 12-3. Every plant loses water through transpiration.

Photosynthesis

Why aren't the leaves of the tree in Figure 12-4 green? If you live in a place that has changing seasons, you know that this photograph was taken in the fall. Many trees and bushes change color as the days get shorter and the weather grows colder. Plants may change from green to red, brown, yellow, or orange. Some show all of these colors at the same time. These colors are the results of pigments like the carotenoids that are present in the green leaves. In the spring and summer, the green pigment chlorophyll is so abundant in the leaves that it covers up, or masks, all other pigments. In the fall, plant cells stop producing chlorophyll, and the other pigments become visible. Chlorophyll is a pigment that traps light

Figure 12-4. Deciduous trees like this red maple change color in the fall, then drop their leaves.

energy for plants to use in making food. **Photosynthesis** is the process in which plants use light energy to produce food.

What do plants need besides light to make food? During photosynthesis, a plant makes food from light energy, carbon dioxide, and water in a series of chemical reactions. Some of the light energy trapped in the chlorophyll is used to split water molecules into hydrogen and oxygen. Light energy is then used to join hydrogen and carbon dioxide together to form a new molecule of sugar. The sugar formed is glucose, the food a plant uses for maintenance and growth. The process is illustrated in the following equation:

$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} + \text{light energy} \xrightarrow[\text{chlorophyll}]{} \underset{\text{sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2}$$

It takes six molecules of carbon dioxide and six molecules of water to form one molecule of sugar, plus six molecules of oxygen. That is, the products of photosynthesis are sugar and oxygen.

MINI-Lab

How can the use of carbon dioxide by plants be shown?

Pour 25 mL of phenol red solution into a beaker. Note the original color. Blow carefully through a straw. **CAUTION:** *Do not inhale.* Note the color change. What have you added to the solution? Repeat this procedure in a second beaker. Add an *Elodea* sprig to each beaker. Place under a bright light for 15 minutes, observing every 5 minutes. What do you see? *Relate* any changes you see to photosynthesis.

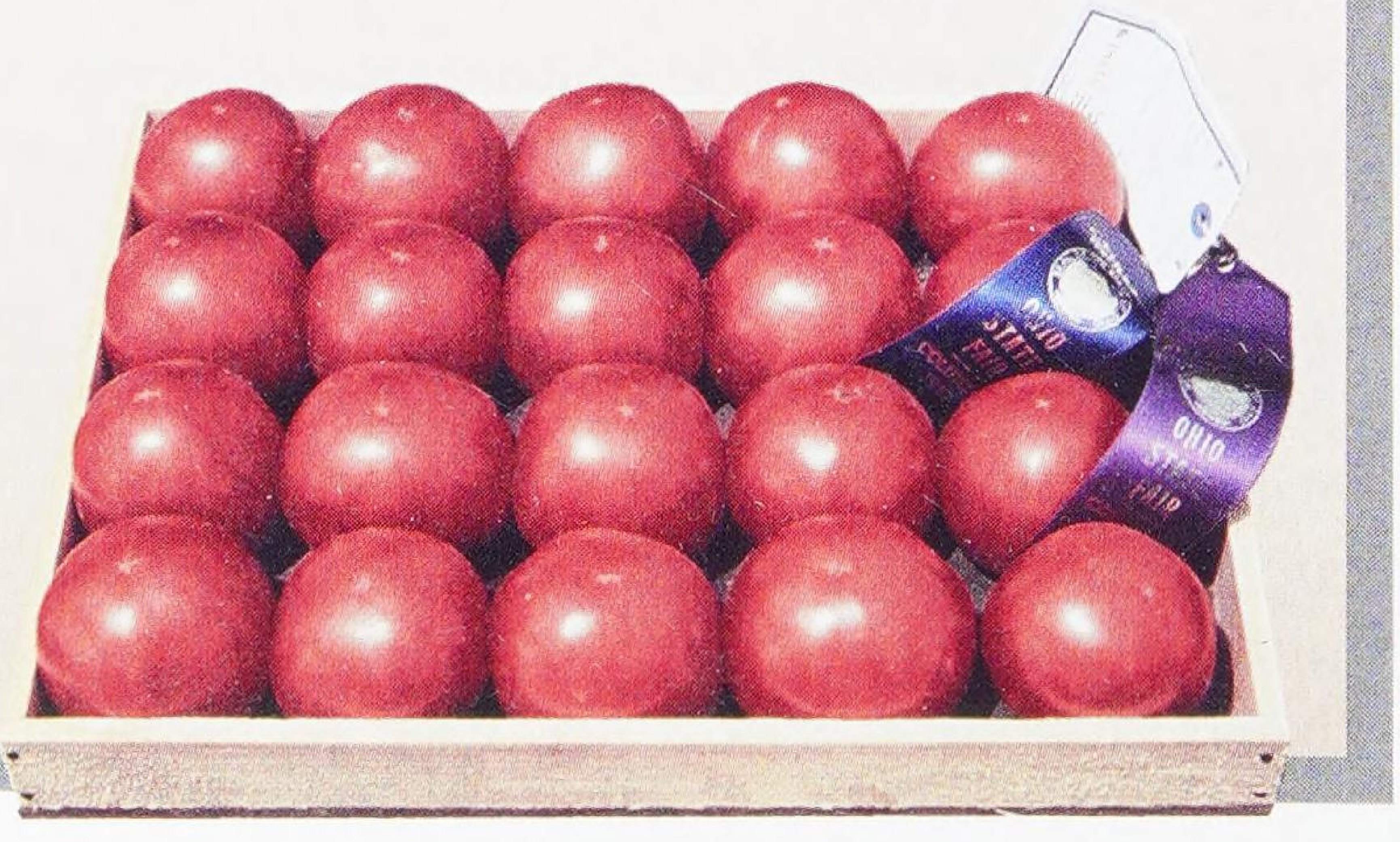
TECHNOLOGY

Designer Plants

Using a gun that blasts tiny DNA-coated metal spheres into plant cells, scientists are trying to change the genetic codes of food crops such as wheat, rice, and corn.

Microbeads are a technique for introducing new genetic information into monocot plants such as grains. Cell transplants and gene transfers to plant embryos work well on dicots such as soybeans, tomatoes, and potatoes. The tomato mosaic virus costs the food industry $50 million each year, but resistant tomato plants can now be made available. In other tomato plants, a transfer gene provides DNA that blocks production of a chemical that triggers decay. As a result, the tomatoes have a much longer shelf life.

Think Critically: How could these designer plants benefit both farmers and consumers?



What happens to these products in a plant? Plant cells make use of the products of photosynthesis in many ways. Some of the oxygen is used by the plant cells for respiration. The rest of the oxygen is released and leaves the leaf through stomata. Sugar produced by plants is used for plant life processes such as growth, or it can be stored in the roots or stems of the plant as sugar, starch, or other products. When you eat beets, carrots, potatoes, or onions, you are eating stored food.

Why is photosynthesis important to living things? The most important role of photosynthesis is food production. Photosynthetic organisms are producers that provide food for nearly all the consumers on Earth. Secondly, through photosynthesis, plants remove carbon dioxide from the air and produce the oxygen that most organisms need to stay alive. As much as 90 percent of the oxygen entering our atmosphere today probably comes as a result of photosynthesis.

Respiration

Look at the photographs in Figure 12-5. Do these organisms have anything in common? All of these organisms are similar in that they break down food to produce energy. **Respiration** is the process by which organisms break down food to release energy. Respiration that uses oxygen to break food down chemically is called aerobic respiration. Aerobic respiration occurs in the mitochondria of all eukaryotic cells. The overall chemical equation for aerobic respiration is:

$$\underset{\text{sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} + \text{energy}$$

Connect to... Physics

Light energy can be described by waves or particles. Particles of light energy are called photons. One photon of light contains enough energy to excite a chlorophyll molecule. What color of light is least used by a chlorophyll molecule? (HINT: What color do most leaves reflect in mid-summer?)

In Your JOURNAL

In most parts of the world, trees lose their leaves in fall and winter. What continues to produce oxygen during these seasons? **In your Journal,** after doing some researching, discuss what you think keeps the world supplied with oxygen.

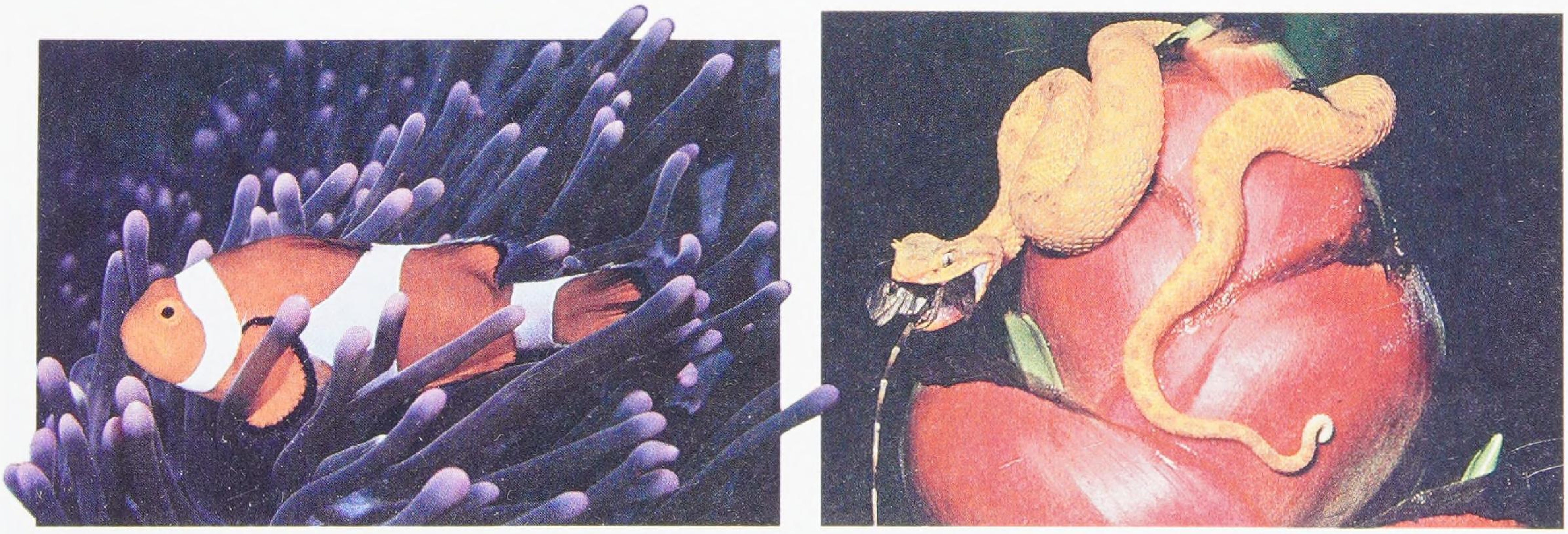


Figure 12-5. Respiration enables organisms to release energy that is found in the chemical bonds of food. Respiration occurs in all cells of all organisms.

Table 12-1

COMPARING PHOTOSYNTHESIS AND RESPIRATION

	Energy	Raw Materials	End Products	In What Cells
Photosynthesis	stored	light energy, water, carbon dioxide	sugar, oxygen	cells with chlorophyll
Respiration	released	sugar, oxygen	water, carbon dioxide, energy	all cells

Is the equation for respiration familiar? How does it relate to the chemical reaction for photosynthesis? During photosynthesis, energy is stored in food. Photosynthesis occurs only in cells that contain chlorophyll, such as those in the leaves of plants. *Respiration occurs in all cells of all organisms.* Respiration releases energy from food. Table 12-1 compares the two processes of photosynthesis and respiration.

Why do plant cells need energy? Plants use energy to build and repair their cells, tissues, and organs. Sugar is used to make cellulose to build cell walls. Plants use energy from the food they make during photosynthesis for growth and reproduction.

MINI-Lab

How can respiration in yeast be shown?

Pour 10 mL of bromothymol blue into a test tube. Add 20 drops of yeast suspension and 10 drops of sugar solution. What color change is seen after 5 minutes? 10 minutes? 15 minutes? What has caused this color change? *Compare* the results of the MINI-Lab on page 278 with the results of this MINI-Lab.

SECTION REVIEW

1. Explain how carbon dioxide and water vapor are exchanged in a leaf.
2. Describe the chemical reactions that take place in photosynthesis and respiration.
3. Why are photosynthesis and respiration important?
4. **Apply:** Humidity is caused by water vapor in the air. Why is humidity high in lush tropical rain forests?
5. **Connect to Earth Science:** What gas is put into the atmosphere as a result of photosynthesis?

Skill Builder

Comparing and Contrasting

Compare the raw materials and end products of photosynthesis and respiration and what happens to the energy involved in each process. If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.

ACTIVITY 12-1

Stomata in Leaves

Problem: *Where are stomata in lettuce leaves?*

Materials

- lettuce in dish of water
- coverslip
- microscope
- microscope slide
- salt solution
- forceps

Procedure

1. Remove a piece of an outer green leaf of the lettuce. Choose a leaf that is turgid (stiff) from absorbing water in the dish.
2. Bend the leaf back and use the forceps to strip off some of the transparent tissue covering the leaf. This is the epidermis. Prepare a wet mount of a small piece of this tissue.
3. Examine the preparation under low and then high power on the microscope. Draw and label the leaf section in your data table.
4. Note the location and spacing of the stomata. Count the number of stomata that are open.
5. Make a second wet mount of the lettuce leaf epidermis. This time place a few drops of salt solution on the leaf. *Predict* what will happen to the stomata.
6. Examine the preparation under low and then high power on the microscope. Draw and label the leaf section in your data table.
7. Note the location and spacing of the stomata. Count the number of stomata that are open.

Data and Observations

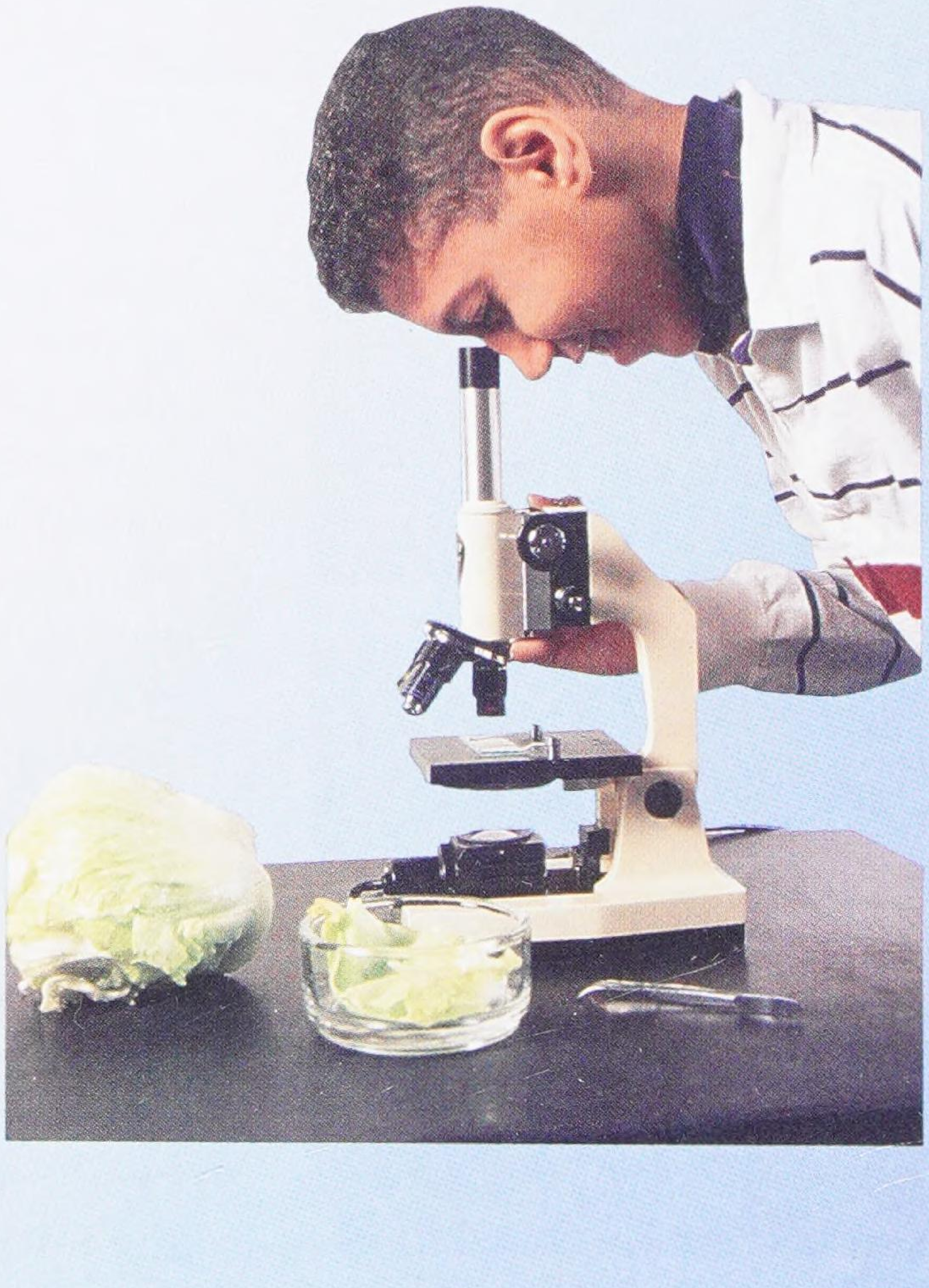
Water Mount	Salt Solution Mount
Number of stomata open	**Number of stomata open**

Analyze

1. Describe the guard cells around a stoma.
2. How many stomata did you see in each leaf preparation?
3. Are guard cells different from the other cells of the leaf epidermis? Explain.
4. **Hypothesize** why a lettuce leaf becomes stiff in water.

Conclude and Apply

5. Were more stomata open or closed in the salt solution? Explain.
6. What can you *infer* about the function of stomata in a leaf?
7. How can you *conclude* that guard cells take part in photosynthesis?



12-2 Plant Responses

New Science Words

stimulus
tropism
auxin
photoperiodism
long-day plants
short-day plants
day-neutral plants

Objectives

- Explain the relationship between stimuli and tropisms in plants.
- Differentiate between long-day and short-day plants.
- Explain the relationship between plant hormones and responses.

What Are Plant Responses?

If you touch the leaflets of the *Mimosa pudica* tree in Figure 12-6a, its leaflets will close up, as shown in Figure 12-6b. Why does this happen? The leaflets fold up in response to the stimulus of being touched. A **stimulus** is anything in the environment that causes a change in the behavior of an organism. The response of a plant to a stimulus is a **tropism.** Most plants respond to stimuli by growing. Tropisms can be positive or negative, that is, result in growth toward or away from the stimulus. Plants respond to stimuli by changing their behavior.

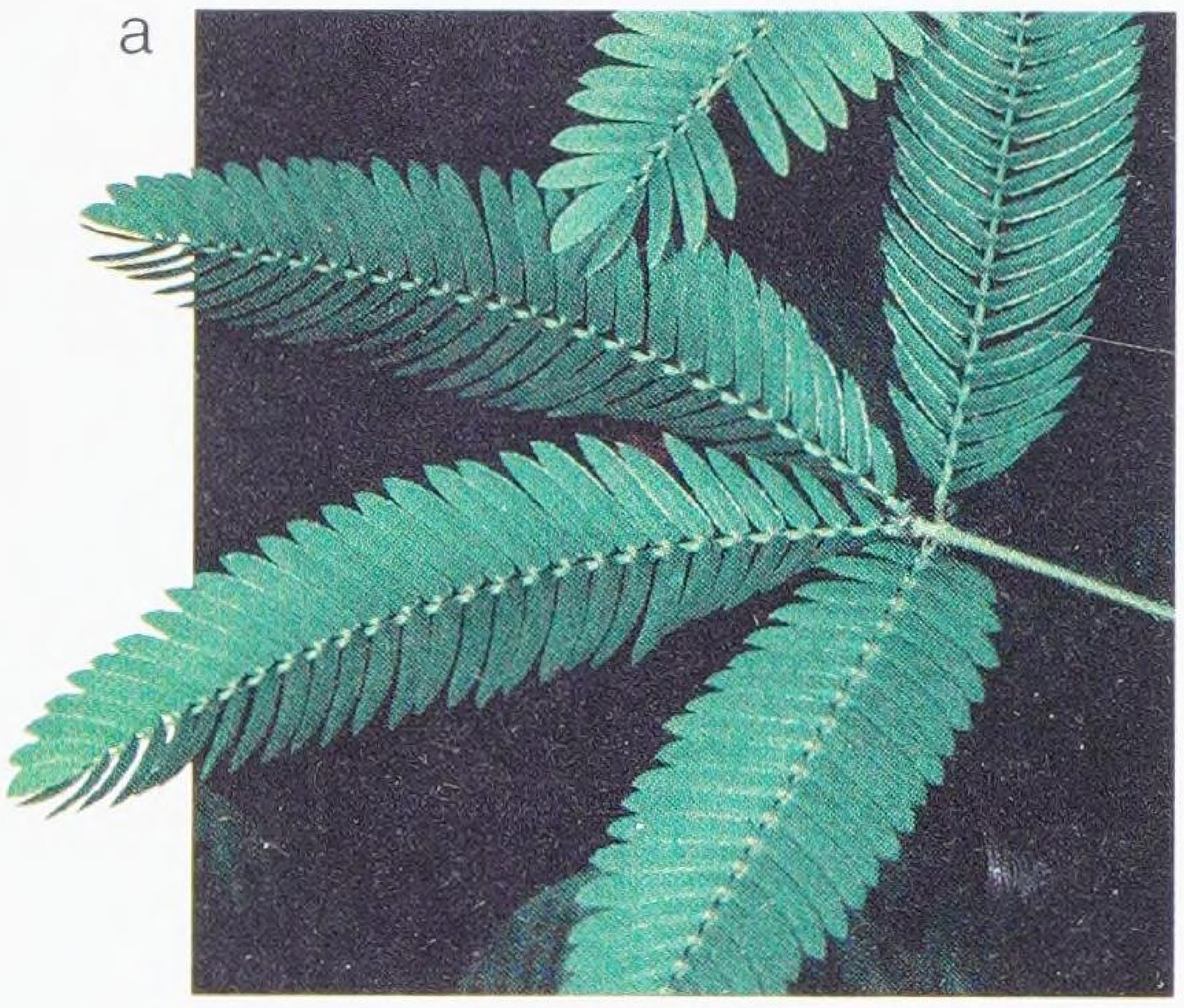
Touch is one stimulus that results in a change in a plant's behavior. Plants also respond to the stimuli of light, gravity, temperature, and amount of water. Some of the responses of plants are the result of plant hormones or chemical reactions in plant cells.

Did you ever see a plant that appeared to be leaning toward a window? Light is an important stimulus to plants. Plants respond to sunlight by growing toward it. The growth response of a plant to light is called *phototropism.* When the plant responds to light by growing toward it, the response is a positive phototropism. An example of negative phototropism occurs when roots of a plant respond to light by growing away from it.

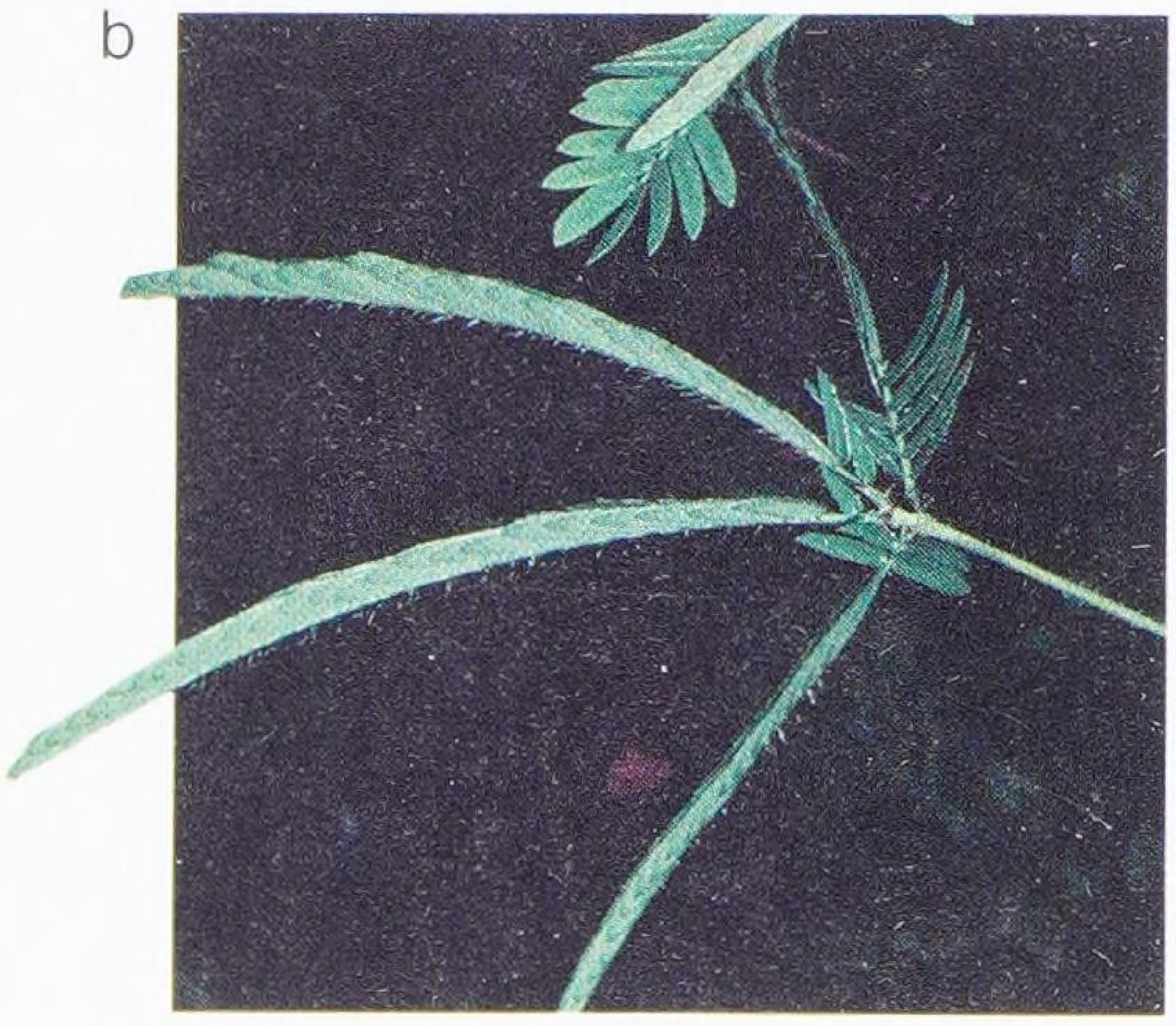
The growth response of an organism to gravity is called *gravitropism.* Plant roots tend to grow downward and the stems to grow upward. The downward growth of a plant's roots in response to the force of gravity is a positive gravitropism. Upward growth of the plant's stem away from the force of gravity is called negative gravitropism.

Figure 12-6. The *Mimosa* plant's leaflets (a) respond to touch by folding up (b). The response to touch is called *thigmotropism.*

a



b



PROBLEM SOLVING

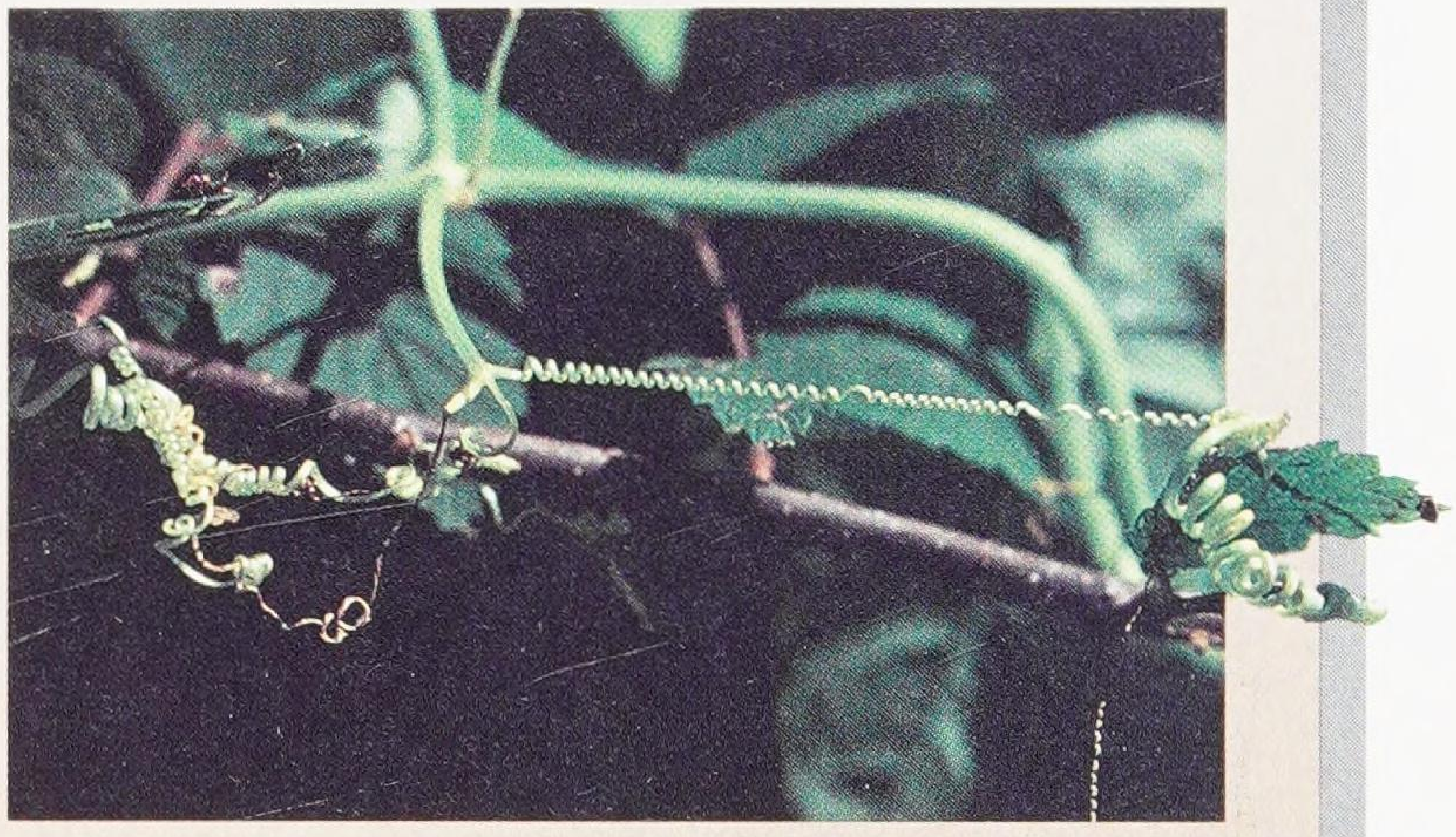
How Do Plants Climb Fences?

While emptying the garbage at the back of his family's restaurant, Hazizi noticed some small plants growing near the fence. Over the next month, Hazizi stopped to look at these plants whenever he helped at the restaurant. As the plants grew, Hazizi noticed little twisted leaves growing out of the sides of the stems. These twisted leaves looked like the metal springs underneath his mattress.

One day Hazizi noticed that a plant seemed to be caught on the fence. He very carefully untwisted the curly leaves that were wrapped around the metal wires of the fence. But the next afternoon, two of the twisted leaves again were wrapped around the wires of the fence. This time Hazizi did not try to untangle them.

A week later Hazizi saw that every plant growing near the fence was climbing slowly up the fence by using the special twisted leaves. How were the plants able to cimb the fence?

Think Critically: What caused the plants to twist their leaves around the fence wires?



Plant Responses and Plant Hormones

In garden centers and greenhouses pots in which seedlings are grown are turned every few days. They do this because the seedlings lean toward the sunlight. As you have learned, this is an example of positive phototropism. But why do the seedlings respond to light in this way?

Plant tropisms are controlled by plant hormones, which are chemical substances that affect growth. An **auxin** is a type of plant hormone. Auxins cause plant stems and leaves to exhibit positive phototropism. If light shines on a plant from one side, the auxin moves to the shaded side of the stem. The auxin causes cells on the shaded side of the stem to grow longer than cells on the lighted side. This causes the stem to curve toward the light.

Ethylene gas, a simple chemical compound of carbon and hydrogen, is another plant hormone. Many plants produce ethylene gas, which causes fruits to ripen.

Connect to... Earth Science

The yearly motion of Earth around the sun is called its revolution. Earth is tilted during orbit, and as a result, seasons are produced. Seasons are times when the photoperiods change. Describe the four seasons in terms of photoperiods, explaining which would produce long-day and short-day plants.

When fruits such as oranges, tomatoes, grapes, and bananas are picked before they have ripened, they stay green because their cells won't produce ethylene. Growers and shippers of fruit found out that it doesn't matter to the fruit where ethylene comes from for ripening. Growers now pick fruit before it is ripe. Shippers treat the picked fruit with ethylene gas during shipping. By the time fruit arrives at the store, it has ripened.

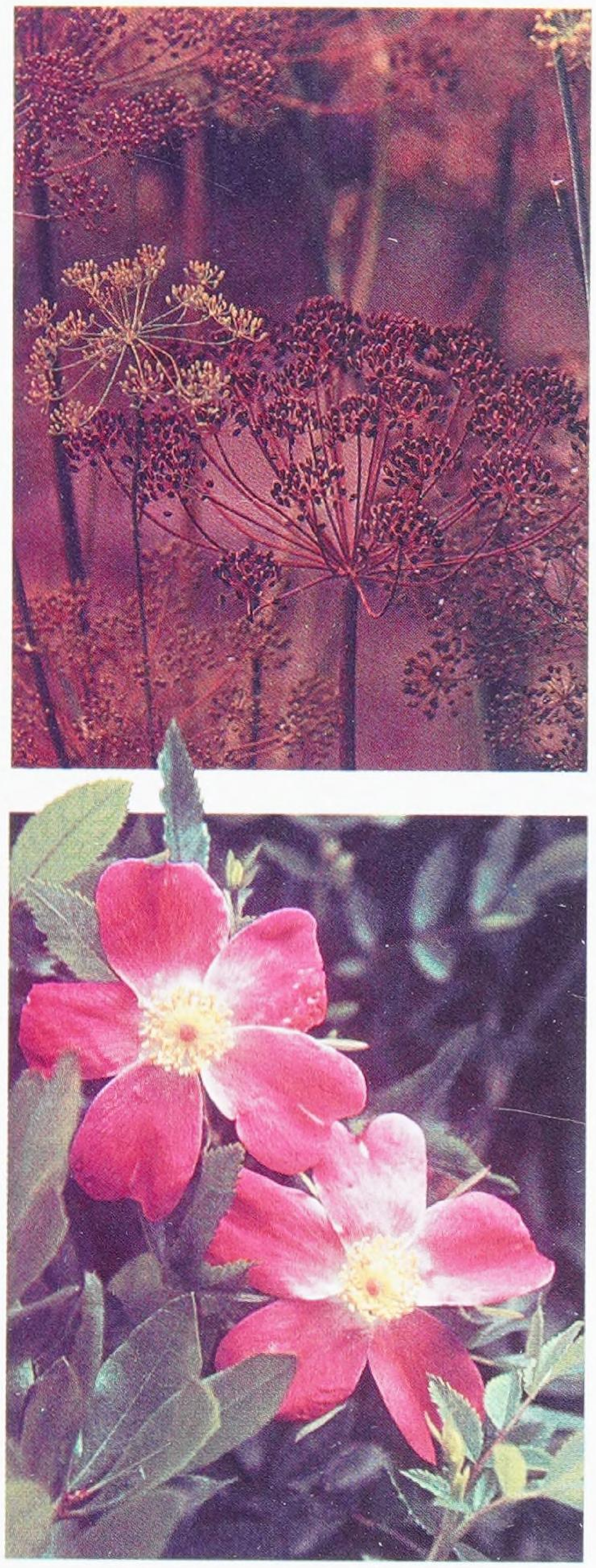


Figure 12-7. Long-day plants such as dill and short-day plants such as primroses flower in response to specific periods of darkness.

Photoperiods

Sunflowers bloom in the summer and cherry trees flower in the spring. Different plant species produce flowers at different times during the year. **Photoperiodism** is the flowering response of a plant to the change in the lengths of light and dark in a day.

Most plants require a specific period of darkness to flower. Plants that require short nights to flower are called **long-day plants.** You may be familiar with long-day plants such as spinach, lettuce, and potatoes. Similarly, plants that require long nights to flower are called **short-day plants.** Some short-day plants are poinsettias, strawberries, and ragweed. Other plants, such as dandelions, corn, and tomatoes, flower over a wide range of night lengths. Plants like these that aren't very sensitive to the number of hours of darkness have a range of flowering times and are called **day-neutral plants.**

SECTION REVIEW

1. Describe the three major forms of tropisms.
2. Compare three different photoperiod responses.
3. Explain how auxins cause positive phototropism.
4. **Apply:** What is the relationship between plant hormones and tropisms?
5. **Connect to Physics:** Find out how a Venus's-flytrap closes up when an insect gets too close.

Skill Builder

Comparing and Contrasting

Different plant parts exhibit positive and negative tropisms. Compare and contrast the responses of roots, stems, and leaves to light. If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.

Plant Relationships 12-3

Objectives

- Define and give examples of parasitism.
- Define and give examples of mutualism.
- Describe an example of coevolution.

New Science Words

coevolution

Parasitic Relationships

How does a plant that has no chlorophyll get its food? The dodder plant is a parasite. A parasite is an organism that lives on or in an organism of a different species and gets its nutrients from that organism. Although most plants make their own food by photosynthesis, parasitic plants get nutrients from other plants or animals. Parasitism can occur between any two species of organisms. It is one of the relationships plants have with other organisms.

The Indian Pipe in Figure 12-8 is a ghostly white parasitic plant often mistaken for a fungus. Because it has no chlorophyll, it must get its food from other sources, such as the rotting leaves and stems of other plants.

Several kinds of animals are parasites of plants. Scale insects and aphids suck out the sap from plants. If the scale insect or aphid populations increase to very high levels, plants will eventually die from loss of food and water. Most parasites do not kill their hosts. What would probably happen if they did?

Connect to... Chemistry

Insect-eating plants, such as pitcher plants and sundews, often grow in areas where heavy rains wash nitrogen from the soil. Few other plants can grow there. *Infer* how these plants get the nitrogen they need if nitrogen is not available from soil.

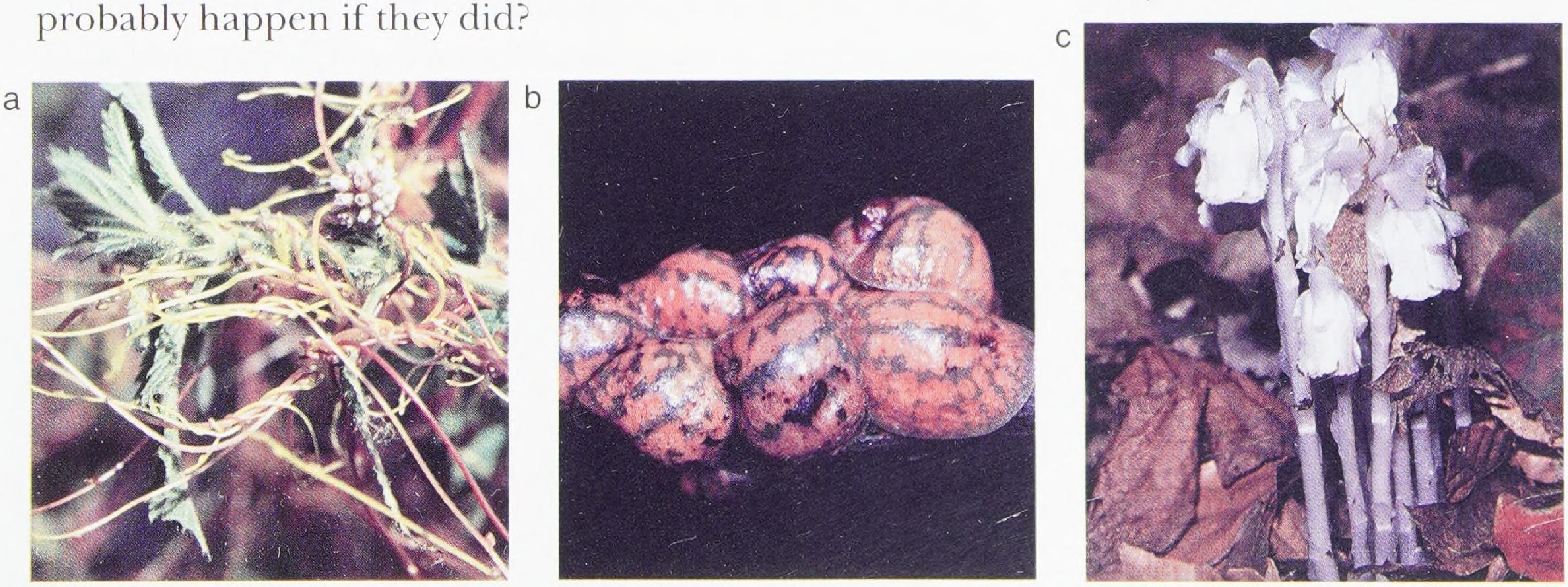


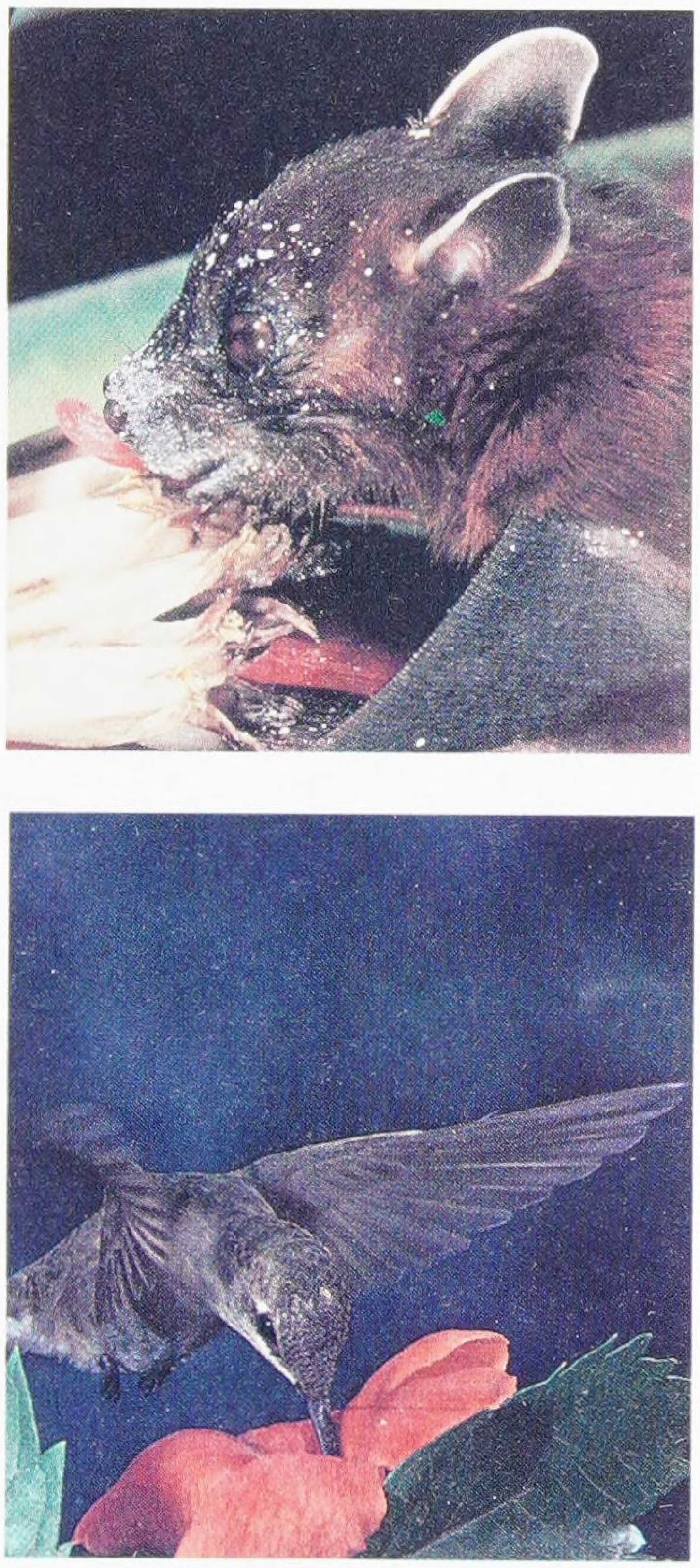
Figure 12-8. Organisms like orange dodder plants (a), scale insects (b), and Indian Pipes (c) are parasites.

Mutual Relationships

What kind of relationship can you infer between the bat and the flower in Figure 12-9? The bat visits the flower to eat the nectar it produces. When the bat puts its head into the flower, some pollen is rubbed off onto the animal's fur. The bat travels from one flower to the next, pollinating flowers at each stop. Both flowers and bat benefit from their relationship. A relationship between two species that benefits both is called mutualism. Mutualism often occurs between plants and their pollinators. Most angiosperms pollinated by insects, birds, or mammals have mutualistic relationships with their pollinators.

Other mutualistic relationships that do not involve pollination occur between plants and insects. One such relationship has evolved between the thorny acacia trees of Central America and Africa and a species of ant. The ants hollow out and occupy the inside of the acacia tree's thorns. The acacias produce a sweet sap that the ants eat. The tree provides both shelter and food for the ants. The ants attack and bite large insects and herbivores that browse on the acacias. As a result, these animals stay away. Acacia trees without a mutualistic relationship with ants grow more slowly and have a higher death rate.

Figure 12-9. The bat and the bird and the flowers they pollinate have mutualistic relationships. Relationships like these may be a result of coevolution.



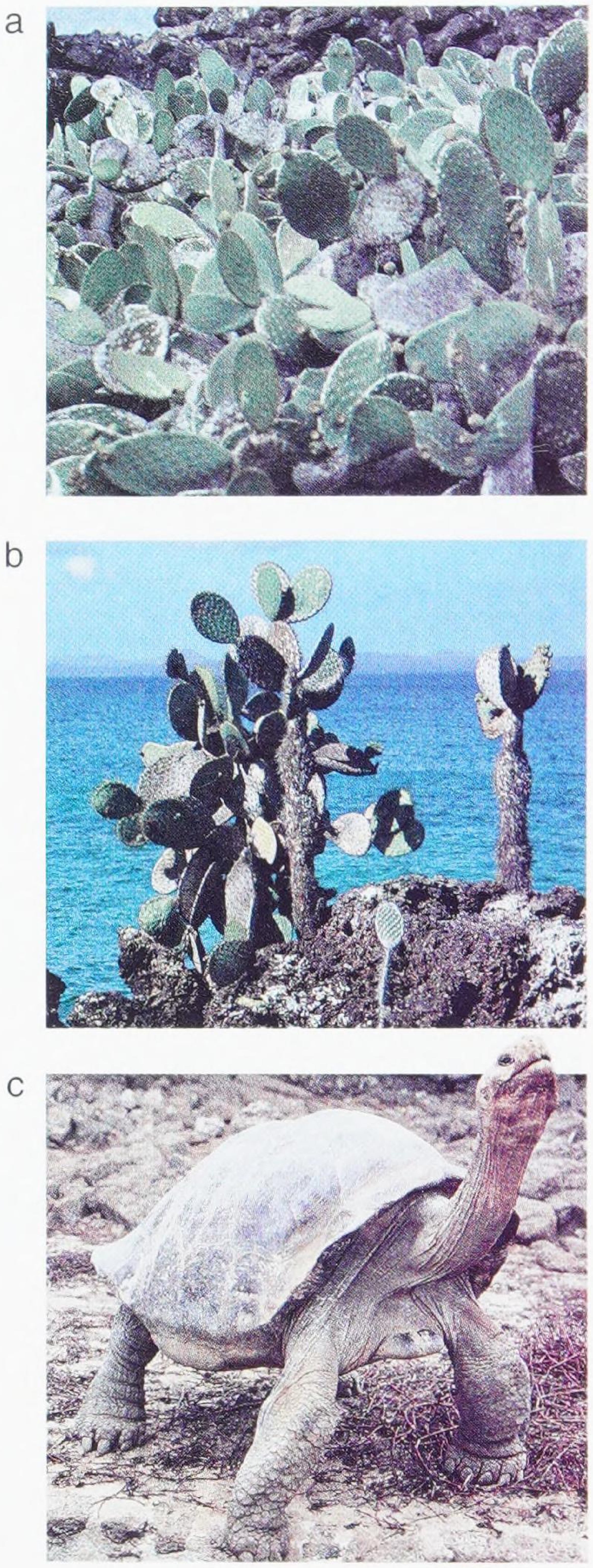
Coevolution

An evolutionary relationship that sometimes occurs between specific plants and animals is coevolution. **Coevolution** occurs when two species of organisms evolve structures and behaviors in response to changes in each other over a long period of time. The pollination of flowers by animals is the most common example of coevolution.

Insects and birds already existed before flowering plants appeared. When dinosaurs died out, so did many gymnosperms, leaving room for new species to emerge. Insects, birds, mammals, and angiosperms evolved together and interacted in ways that improved each species' chances for survival. Today, flowers that depend on bees for pollination often are colored blue, yellow, or ultraviolet. Bees see these colors best and so are attracted to flowers with these colors. Flowers pollinated by moths are usually white, with a strong scent. Moths generally fly at night and may be directed to flowers by scent as well as color. Birds can see red and orange very well. They pollinate flowers such as the red and orange bird-of-paradise flower.

Another example of coevolution can be found in the Galapagos Islands once visited by Charles Darwin. Opuntia cacti are found on several of these islands. On some islands, the cacti grow as short bushy forms near ground level. On other islands, this same species of cactus grows as taller, upright tree forms. Galapagos tortoises eat opuntia cactus, but there are no tortoises on islands that have short bushy cacti. Galapagos tortoises are found on islands where the cacti grow as trees. Tortoises on these islands have shells that arch up high above their heads. These tortoises can stretch their necks up high in order to feed. Grazing by the tortoises on these islands apparently eliminated the short opuntias that grew close to the ground. The taller forms survived to reproduce, resulting in the evolution of tall, upright tree forms. As the opuntias evolved into upright forms, the tortoises that had higher shells were able to graze higher in the opuntia trees on their islands. The tortoises with higher shells continued to find food and reproduce. Scientists hypothesize that these tortoises favored the evolution of taller opuntia cacti, and the taller cacti favored the evolution of tortoises with higher shells. These two species favored the evolution of some adaptations in one another.

Figure 12-10. Short opuntia cacti (a) grow on islands without tortoises, whereas taller tree forms of cacti (b) are only found where tortoises live (c).



SECTION REVIEW

1. What is a parasitic relationship?
2. Describe the features of a mutualistic relationship and give an example.
3. What is coevolution?
4. **Apply:** Some flowers are pollinated by flies that lay eggs on dead or decaying animals. What do you think these flowers smell like? How is this adaptation helpful?
5. **Connect to Earth Science:** How are evolution of living things and evolution of Earth similar?

Hypothesizing

Skill Builder

In a particular relationship between a kind of orchid and a bee, the orchid flower looks and smells like the female bee. The male bee is attracted to the flower and helps in the pollination. Make a hypothesis about the evolutionary history of these species. If you need help, refer to Hypothesizing in the **Skill Handbook** on page 686.

SCIENCE & SOCIETY

12-4 The Treasure of Tropical Plants

New Science Words

ethnobotany

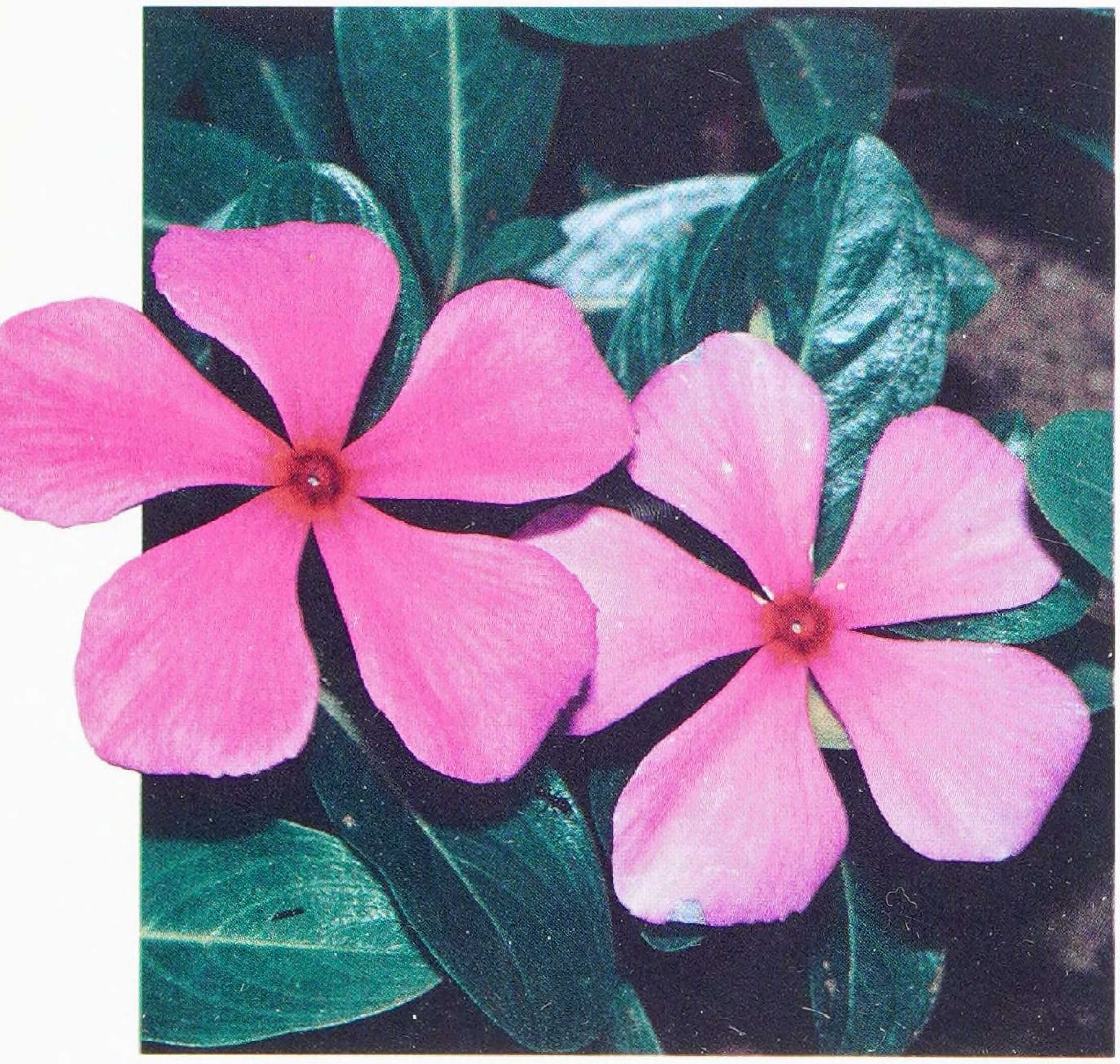
Objectives

- Identify the role of plants in medicine.
- Describe how destruction of tropical forests may destroy plant and animal species that could have beneficial uses in modern medicine.

Medical Miracles from the Tropics

Have you ever imagined yourself as the discoverer of a new drug that could be used to treat what was once an incurable disease? Surely, years and years of research are required to develop such miracle drugs! In fact, many of the drugs and medications we use today came from common plants. The knowledge of these plants was gained from ancient cultures in tropical regions of the world. Rosy periwinkle, for example, is a plant that grows on the island of Madagascar off the coast of Africa. A total of 75 chemicals are derived from this plant, including two that are used to successfully treat childhood leukemia and Hodgkin's disease.

Figure 12-11. Rosy periwinkle is the source of numerous chemicals used to treat disease.



Ethnobotany is the study of how people use plants. Many plants that are used in drugs and other medications were first discovered through such studies. Today, researchers document the knowledge of traditional healers in tribes that inhabit tropical environments. These healers have been taught about the qualities of local plants and how they can be used for medical treatment. In many instances, this information has never been written down. Rather, it has been handed down by word of mouth over thousands of years. Some ethnobotanists live with tribal groups for a few months every year, collecting specimens, seeds, and flowers, as well as writing down information about how each plant is used. Today, cultures that have used this kind of information are threatened by the destruction of the tropical rain forests where they live.

Thousands of hectares of tropical forests are cut down or burned each day, and as they are, more and more species of animals and plants are lost. Few of the remaining tribes in the tropics have been thoroughly investigated and studied by ethnobotanists. Without documentation of the knowledge of those remaining tribes, the world may suffer great scientific and economic losses.

The National Cancer Institute has seen the urgency of this situation and is taking action. The Institute has awarded millions of dollars to researchers to collect and test species of tropical plants for their ability to stop or slow the growth of tumors. By taking immediate action, researchers may be able to help find the source of such drugs before they are lost forever due to tropical deforestation.

Figure 12-12. Ethnobotantists work with local healers to identify plants with medicinal value.

SECTION REVIEW

1. What are two diseases that can be treated with drugs derived from plants?
2. What work do ethnobotanists do?
3. **Connect to Earth Science:** Use a world map to locate the island of Madagascar off the east coast of Africa. Describe the island and its products.

You Decide!

SCIENCE & SOCIETY

Some people believe that the people of developing countries could take advantage of the plants that have medicinal value. Factories could be developed to extract the chemicals from these plants. This would make jobs and help the economies of these countries. However, such a life-style change could also change the cultures of tribal groups forever. Should countries become involved in developing the resources of plants with medicinal value in this manner?

ACTIVITY 12-2

Plant Tropisms

Problem: *How can tropisms be observed in plant seedlings?*

Materials

- petri dish
- tape
- string
- corn seeds
- paper towel
- water
- ring stand

Procedure

1. Place the bottom of the petri dish on a paper towel, draw around the dish, then cut the circle to fit the dish.
2. Tape the paper in the bottom of the dish.
3. Arrange ten corn seeds at equal distances around the outer edge of the petri dish with all the points of the seeds pointing to the middle of the dish.
4. Tape the seeds to the paper towel.
5. Place another wet towel in the petri dish.
6. Put the cover on the dish and tape it closed.
7. Tape a piece of string to the back of the dish and hang the dish from a ring stand. *Predict* the direction in which roots will grow.
8. After 24 hours, unwrap and open the petri dish to check the seeds. Add water if the seeds or paper are dry. Reseal the dish. Repeat this step to check the seeds daily for the next four days. Draw your observations each day.

Analyze

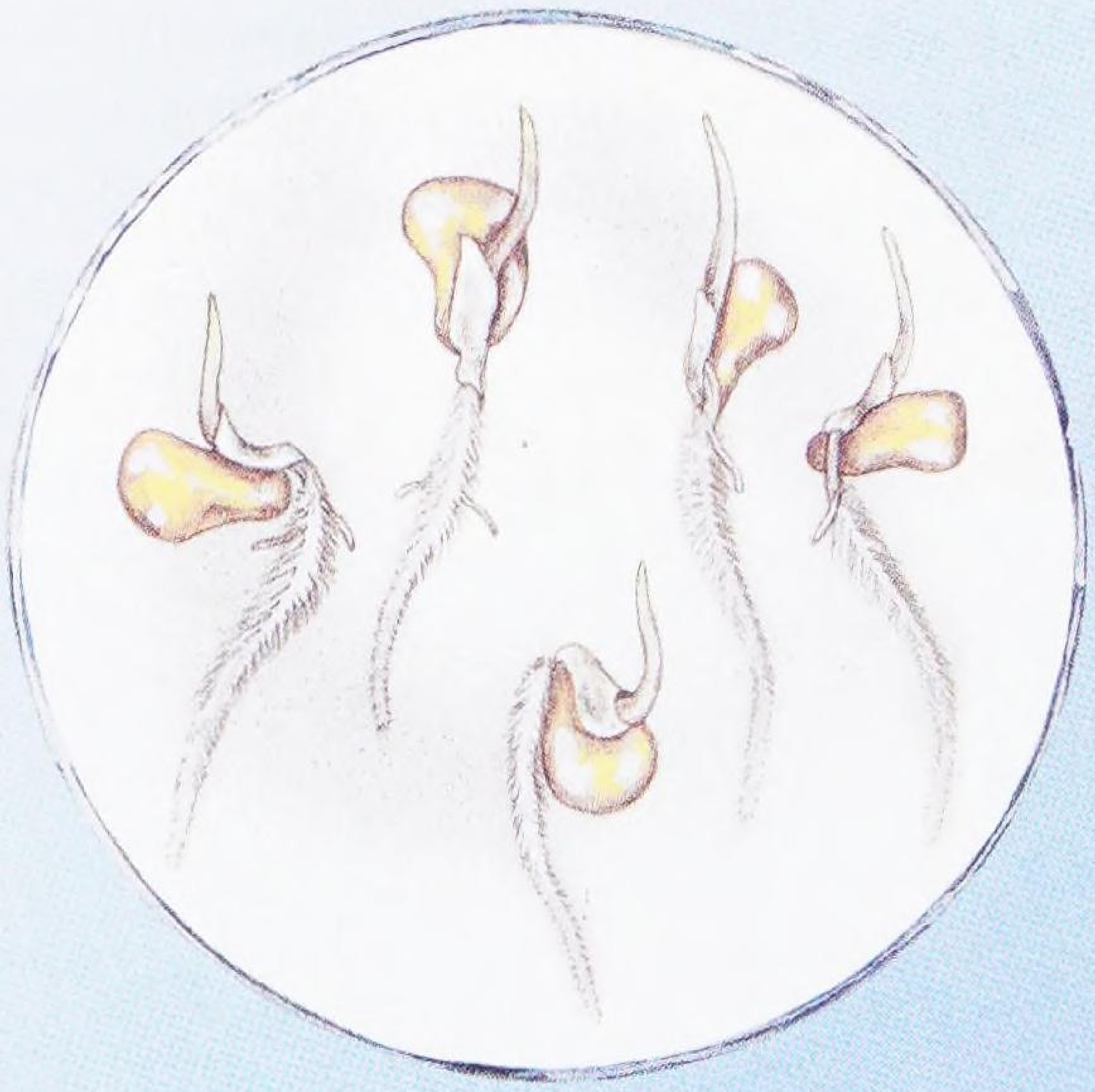
1. When did the seeds begin to germinate?
2. In which direction did the roots appear to grow?
3. In which direction did the stems and leaves appear to grow?
4. Why did you add water to the dish?

Data and Observations

Day	Drawing
Day 1	
Day 2	
Day 3	
Day 4	
Day 5	

Conclude and Apply

5. What name would you give to the movement of the roots?
6. What name would you give to the movement of the stems and leaves?
7. What probably controlled the tropisms you observed?
8. **Design an experiment** to prove that this was gravitropism and not phototropism.



CHAPTER REVIEW

SUMMARY

12-1: Photosynthesis and Respiration

1. Carbon dioxide needed for photosynthesis enters leaves through stomata. Water vapor escapes during this process.

2. Chlorophyll in plants captures sunlight, splits water, and makes glucose and oxygen which are needed by all organisms.

3. Through respiration, energy stored in glucose becomes available for cell activities.

12-2: Plant Responses

1. Plants respond to stimuli by growing toward or away from light, gravity, or water.

2. Plants depend on a critical period of darkness in order to flower.

3. Many tropisms are controlled by hormones produced by plants.

12-3: Plant Relationships

1. Some plants live as parasites, deriving food from other plants.

2. Some plants have mutualistic relationships with other organisms in which both benefit.

3. Plants and animals have coevolved, developing unique relationships with each other.

12-4: Science and Society: The Treasure of Tropical Plants

1. Many medicines used today are derived from common plants.

2. Destroying tropical forests may destroy unknown medicinal plants as well.

KEY SCIENCE WORDS

a. **auxin**
b. **coevolution**
c. **day-neutral plants**
d. **ethnobotany**
e. **long-day plants**
f. **photoperiodism**
g. **photosynthesis**
h. **respiration**
i. **short-day plants**
j. **stimulus**
k. **transpiration**
l. **tropism**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. anything in the environment that affects behavior of an organism
2. a plant hormone
3. flowering response of plant to light
4. using light to make glucose and oxygen
5. positive and negative plant responses
6. loss of water through stomata
7. plants that require short nights to flower
8. plants that are not sensitive to hours of darkness
9. releasing energy from food
10. when species evolve together

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. Stomata open to allow _______ the plant.
   a. sugar into **c.** carbon dioxide into
   b. sugar out of **d.** light into
2. A product of photosynthesis is _______.
   a. CO_2 **c.** H_2O
   b. O_2 **d.** H_2
3. Water, carbon dioxide, and energy are all products of _______.
   a. cell division **c.** growth
   b. photosynthesis **d.** respiration
4. A _______ plant needs short nights to flower.
   a. day-neutral **c.** long-day
   b. short-day **d.** nonvascular
5. Light, touch, and gravity are all examples of _______.
   a. tropisms **c.** responses
   b. growth behaviors **d.** stimuli
6. _______ is a plant's response to gravity.
   a. Phototropism **c.** Thigmotropism
   b. Gravitropism **d.** Hydrotropism
7. Stems, roots, and fruits are all plant parts that may respond to _______.
   a. tropisms **c.** germination
   b. sugar **d.** hormones
8. The _______ is an example of a parasitic plant.
   a. oak **c.** dodder
   b. acacia **d.** dandelion
9. The relationship that occurs between ants and acacias is _______.
   a. parasitism **c.** photoperiodism
   b. independence **d.** mutualism
10. Adaptations of cacti and tortoises over time are examples of _______.
    a. coevolution **c.** mutualism
    b. parasitism **d.** tropism

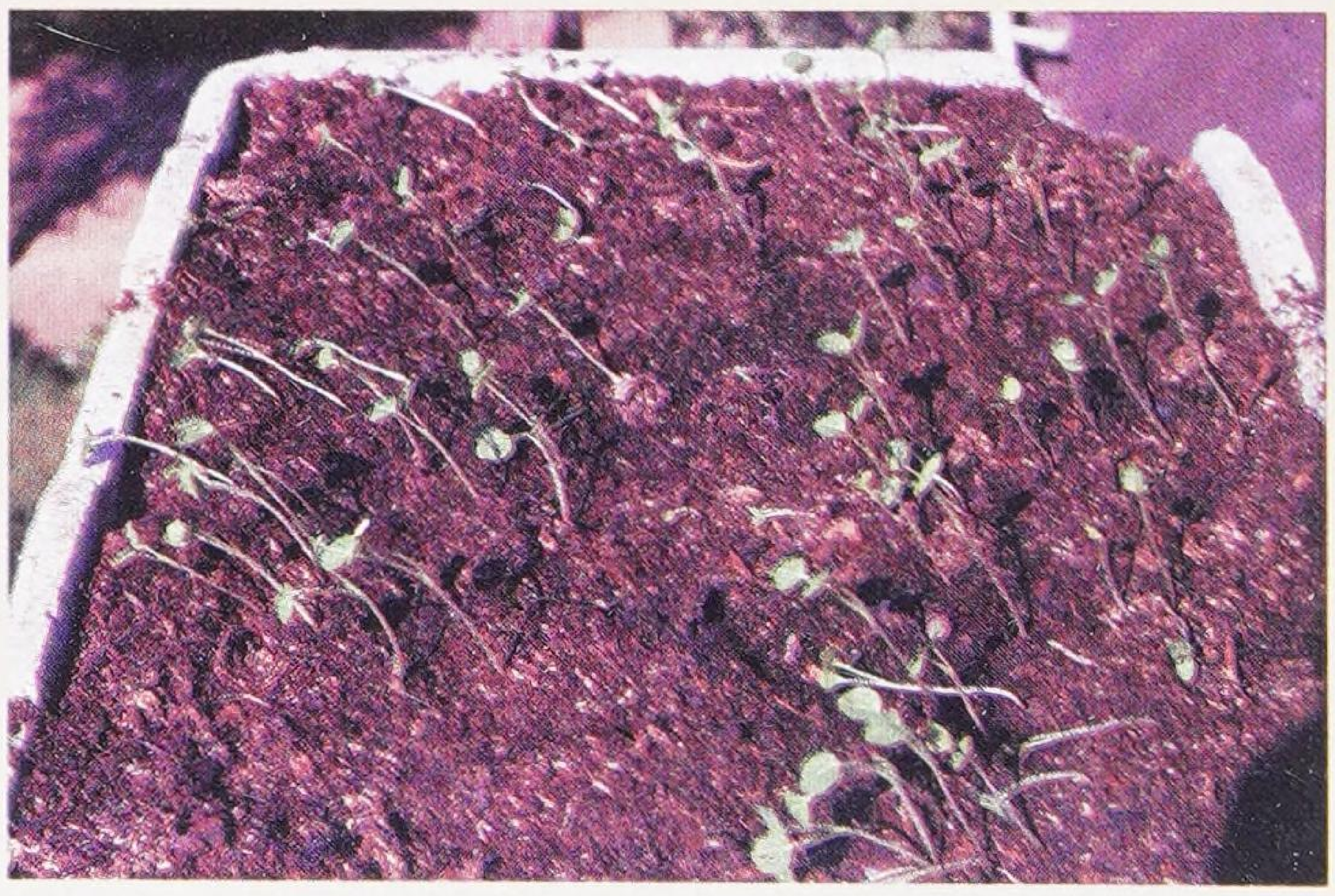
USING LAB SKILLS

11. **Design an experiment** to determine if apples can be used to promote ripening in fruit. State a **hypothesis** clearly. Be sure to identify a control. Then perform your experiment.
12. Using some of the techniques you learned in the MINI-Labs on pages 278 and 280, **design an experiment** to test a **hypothesis** that states: Respiration takes place in plants only at night.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Why is it important that plants grow toward the light as in the photograph below?
14. Why doesn't the dodder plant kill its host?
15. What advantage does the Indian Pipe have living off a plant?



APPLY

16. Growers of bananas pick green bananas, then treat them with ethylene during shipping. Why?

17. Identify the stimulus and response as positive or negative.
—stem grows up
—tendrils grow up
—roots grow down
—plant grows toward light

18. Scientists who study sedimentary rocks and fossils suggest that oxygen did not occur on Earth until plantlike protists appeared. Why?

19. Using plants listed on page 284, design a planting schedule that will have plants flowering from April 15 to September 1.

20. Some tropical flowers have fruity odors and are light in color. Bats that are nocturnal eaters have long tongues and fur on their faces. Explain how these two organisms are examples of coevolution.

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Hypothesizing:** Make a hypothesis as to the action of leaf guard cells in desert plants.
2. **Observing and Inferring:** Based on your knowledge of plants, infer the amount and location of stomata in land and water plants.
3. **Classifying:** Classify each as short-day, long-day, or day-neutral plants by making a chart: corn, chrysanthemum, dandelions, dill, iris, poinsettia, red clover, spinach, sunflower, tomato.
4. **Comparing and Contrasting:** Compare and contrast the action of each chemical on a plant: auxin, ethylene.
5. **Designing an Experiment:** Design an experiment concerning the effect of day length on flowering.

PROJECTS

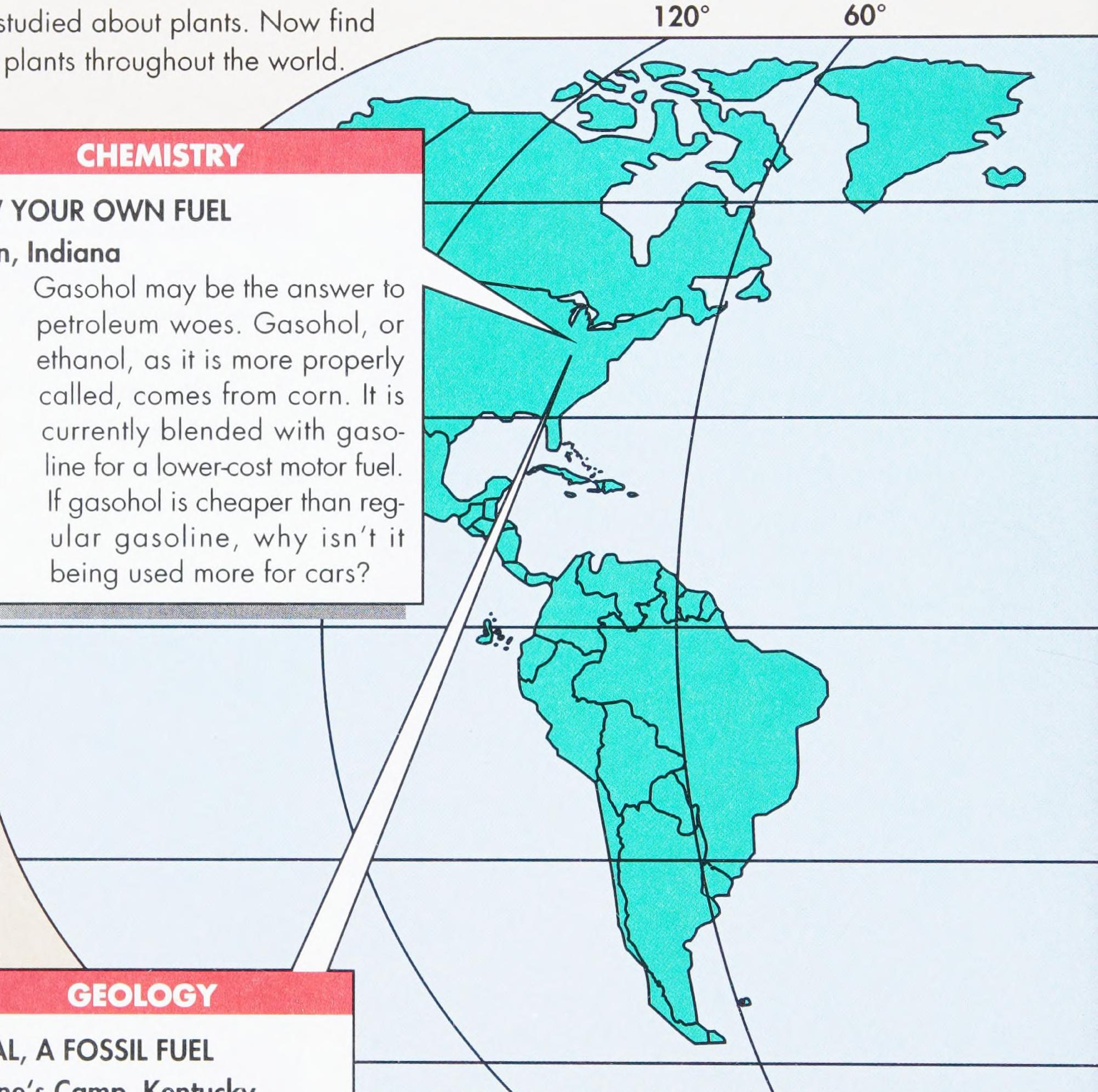
1. **Design an experiment** with a control to test how well plant cuttings root with and without rooting hormone.
2. **Design an experiment** to show the rate of yeast respiration at three different temperatures.
3. Research tropical plants studied for their medicinal value. Illustrate two and describe the culture from which they derive.

UNIT 4

GLOBAL CONNECTIONS

Plants

In this unit, you have studied about plants. Now find out the importance of plants throughout the world.



CHEMISTRY

GROW YOUR OWN FUEL

Breman, Indiana

Gasohol may be the answer to petroleum woes. Gasohol, or ethanol, as it is more properly called, comes from corn. It is currently blended with gasoline for a lower-cost motor fuel. If gasohol is cheaper than regular gasoline, why isn't it being used more for cars?

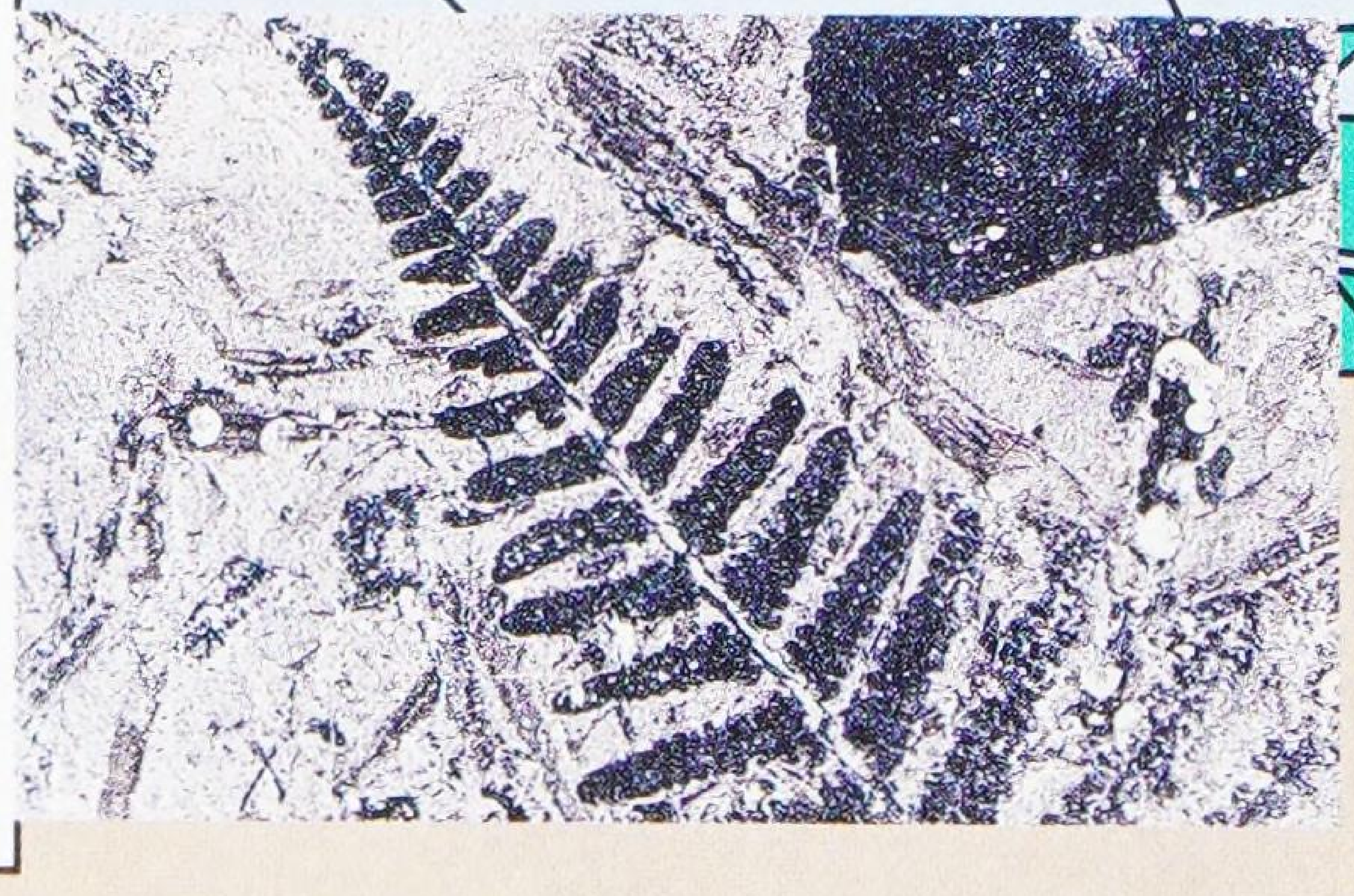
TOTAL PRICE
GALLONS
PRICE PER GALLON
90
unleaded
Gasohol
THIS IS NOT AN ARCO PRODUCT
HOME GROWN
Gasohol

GEOLOGY

COAL, A FOSSIL FUEL

Boone's Camp, Kentucky

Coal has long been a valuable fuel for industry around the world. The coal fields of Kentucky had their beginnings 300 million years ago when they were forests of giant fern and club mosses. How do we know coal fields were once forests?



METEOROLOGY

ACID RAIN THREATENS GERMANY'S BLACK FOREST

Southwestern Germany
Prevailing winds carry sulfur dioxide emissions from France, Italy, and Southern Germany over the Black Forest. Acid rain follows. Some scientists think it is responsible for weakening and killing the trees. Others disagree. What can be done about sulfur dioxide emissions?

GEOGRAPHY

TRAVELING BLOOMS

Ankara, Turkey
The flowers in your garden are world-travelers. Most people think of Holland when they think of tulips. But tulips are natives of Turkey. Poinsettias are natives of Mexico. How do flowers travel so far from their native homes?

HEALTH

MEDICINE FROM THE GARDEN

Antananarivo, Madagascar
Herbalists grew medicinal plant gardens hundreds of years ago. Plants like the Madagascar periwinkle have yielded a cancer-fighting medicine used in treating Hodgkin's disease and leukemia. What are other ways in which plants protect or harm our health?

CAREERS

PLANT PATHOLOGIST

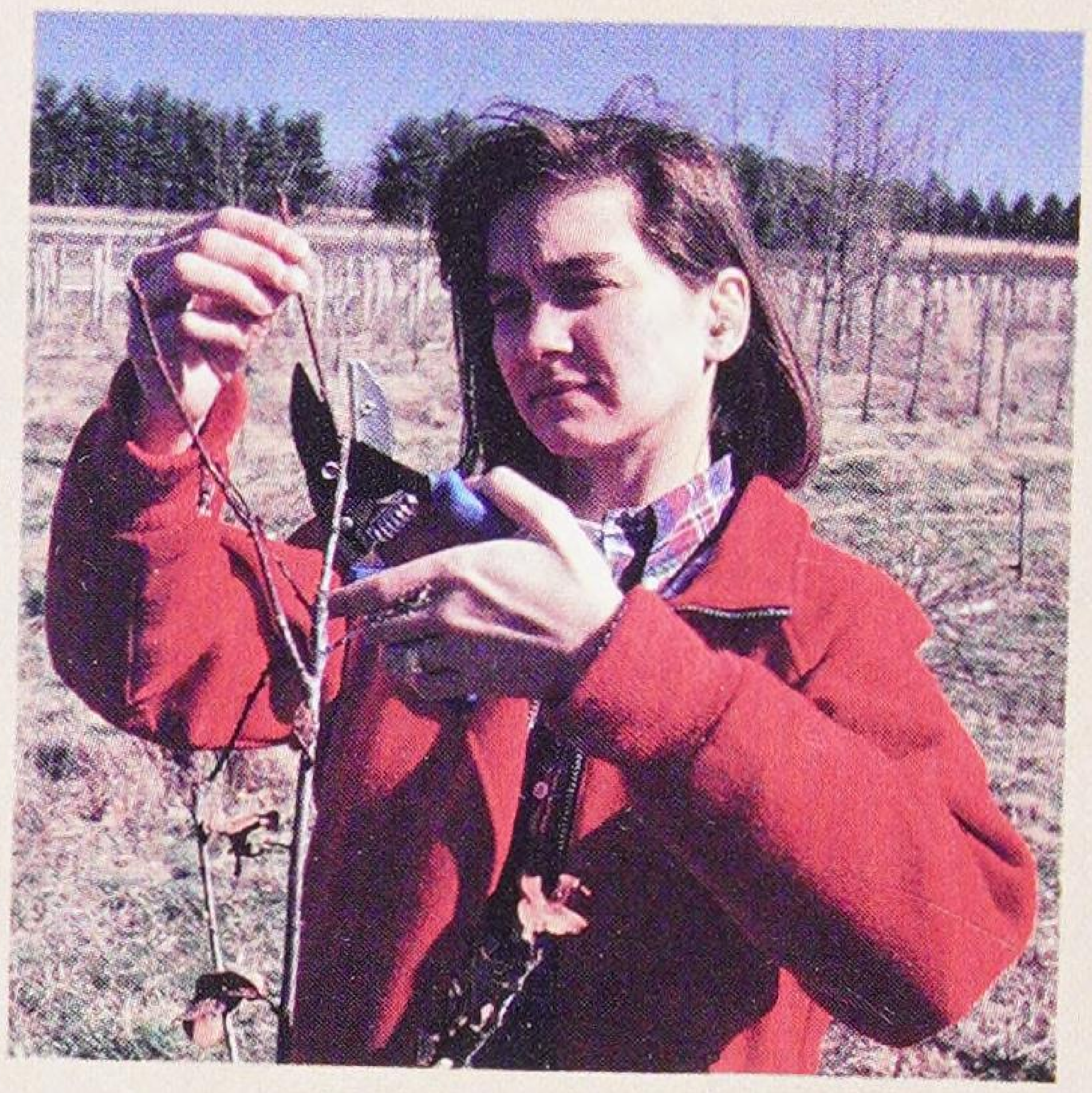
A *plant pathologist* studies the diseases of plants. He or she may specialize in the diseases of one particular species of plants, such as spruce trees, or will specialize in one type of plant pathogen such as viruses, bacteria, fungi, insects, or roundworms.

A plant pathologist needs to study biology, botany, and chemistry. Plant pathologists must have a college degree plus graduate work in the field of plant pathology. A plant pathologist may work in a university research lab, for the Department of Agriculture, or for a plant breeder.

For Additional Information

Contact the American Society of Phytopathologists.

Dr. G. Anderson, Secretary, Botanical Society of America, Dept. of Ecology and Evolutionary Biology, U-43, 75 North Eagleville Rd., Storrs, CT 06269-3043.



PROFESSIONAL GARDENER

A *professional gardener* should have an interest in plants, landscaping, and the conditions plants need for growing. Professional gardeners need to have a knowledge of the kinds of plants to use in a particular setting and what kinds of grass and trees will grow well in a particular soil. He or she should enjoy working out-of-doors.

Professional gardeners must have a knowledge of gardening tools such as mechanical tree planters, pruning devices, and tillers. A professional gardener can learn much through on-the-job training. Programs are also offered through trade schools, community colleges, or county agricultural extension agencies.

For Additional Information

For additional information, contact the Professional Grounds Management Society, 12 Galloway Ave., Suite 1E, Cockneysville, MD 21030.

UNIT READINGS

- Meijer, William. "Saving the World's Largest Flower." *National Geographic,* July 1985.
- McIntyre, Loren. "Humboldt's Way." *National Geographic,* Sept. 1985.

Where the Sky Began,

by John Madson

The following is an excerpt from Where the Sky Began, by John Madson.

Grass and sky would be enough. With only those, the summer prairie would be a smiling, running spread of cloud shadow and wind pattern.

But the tall prairie goes beyond that. From the first greening of spring to the full ripening of autumn, it is spangled by a vivid progression of flowers—a rainbow host that first enamels the burned slopes of early spring and ends months later with great nodding blooms that rise above a man's head. Sometimes as secret and solitary as jewels, but often in broad painted fields, the prairie flowers come on—lavender, indigo, creamy white, pink, coral, gold, magenta, crimson, orange, and palest yellow and blue, their flowers tending from ice to flame....

The prairie flowers come on in waves, each in its own time, some blooming very briefly and others persisting for weeks. Except for a short period early in the growing season, the flowers must compete with a rising tide of grasses. All may begin growing at about the same time; some just mature much later than others, needing months of growth if they are to compete with the towering August bluestem. Spring or fall, prairie flowers are as tall as they need to be.

Most of these earliest prairie flowers appear before mid-May and are never much more than six inches tall. The best known is the pasqueflower, with tulip-like blooms ranging from white to pale lavender, its stem and leaves wearing a dense covering of fine silken hairs. It gives the impression of a small flower trying to keep warm and having a tough time doing so, for pasqueflowers may bloom on bare, exposed crests of old glacial moraines while there are still patches of snow on the sheltered slopes behind them. Brave little flowers, often braver than I. More than once, the lowering clouds and sharp gray winds of late March have hustled me off the prairie before I'd finished photographing the first pasqueflowers. But no matter—at such times their blooms are usually closed anyway.

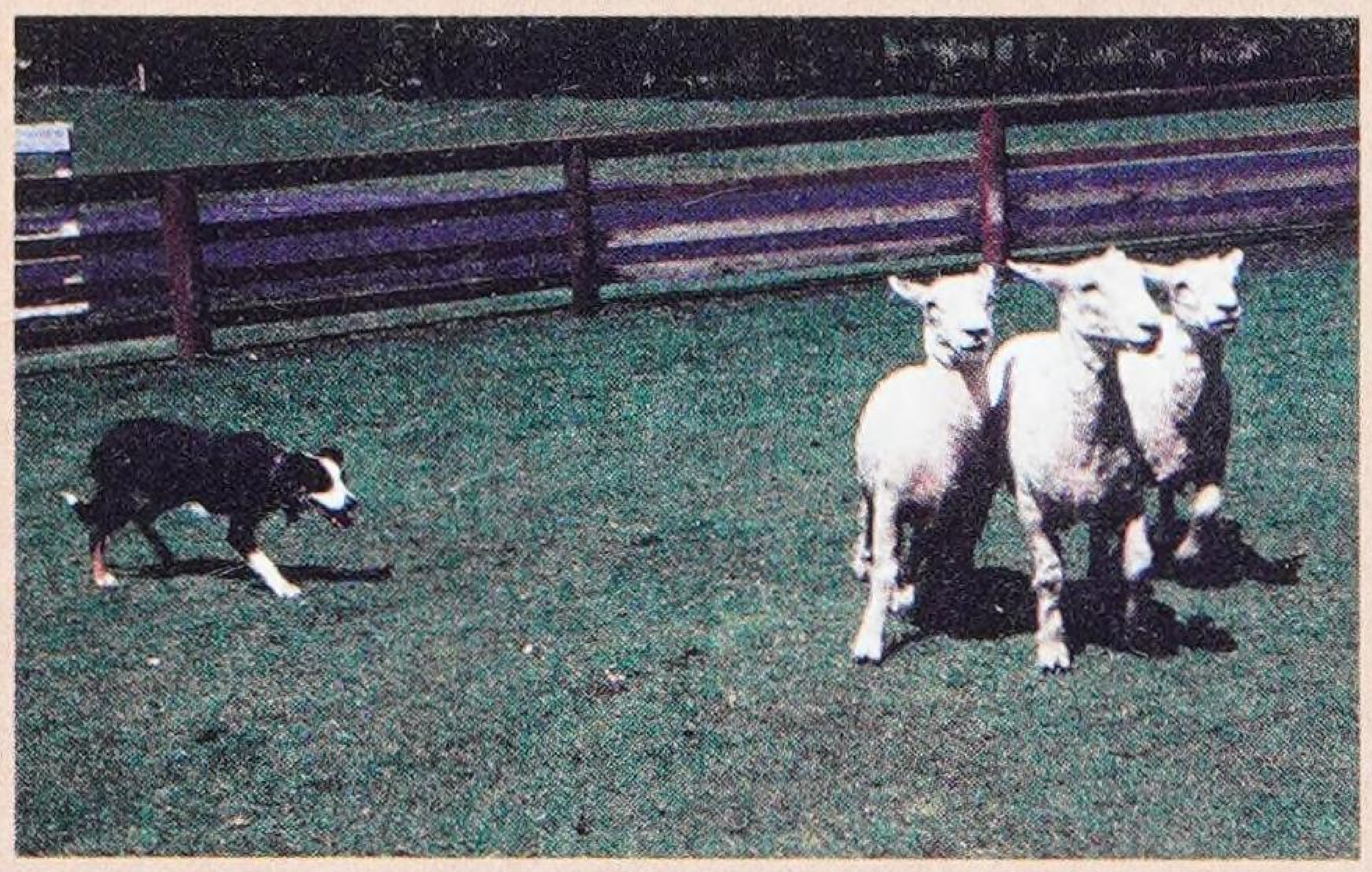
In Your Own Words

- Choose a wildflower, native to your area, and write a brief, descriptive report on its habitat, time of bloom, and any special features of the flower. (Hint: dandelions are not native wildflowers!)

UNIT 5 ANIMALS

What's Happening Here?

These ants aren't preparing to feast on the tiny aphids, but they do get food from them. Ants "farm" aphids for the sweet nectar they produce. The ants keep the aphids in "pens" in underground burrows. In another type of relationship, a border collie protects its sheep from predators such as wolves by keeping the sheep together. Animals have many different types of relationships with one another. Many of these relationships work for the benefit of all the animals involved. You'll learn more about animals and about their relationships in this unit.



UNIT CONTENTS

Chapter 13 Introduction to Animals
Chapter 14 Complex Invertebrates
Chapter 15 Cold-Blooded Vertebrates
Chapter 16 Warm-Blooded Vertebrates
Chapter 17 Animal Behavior

CHAPTER

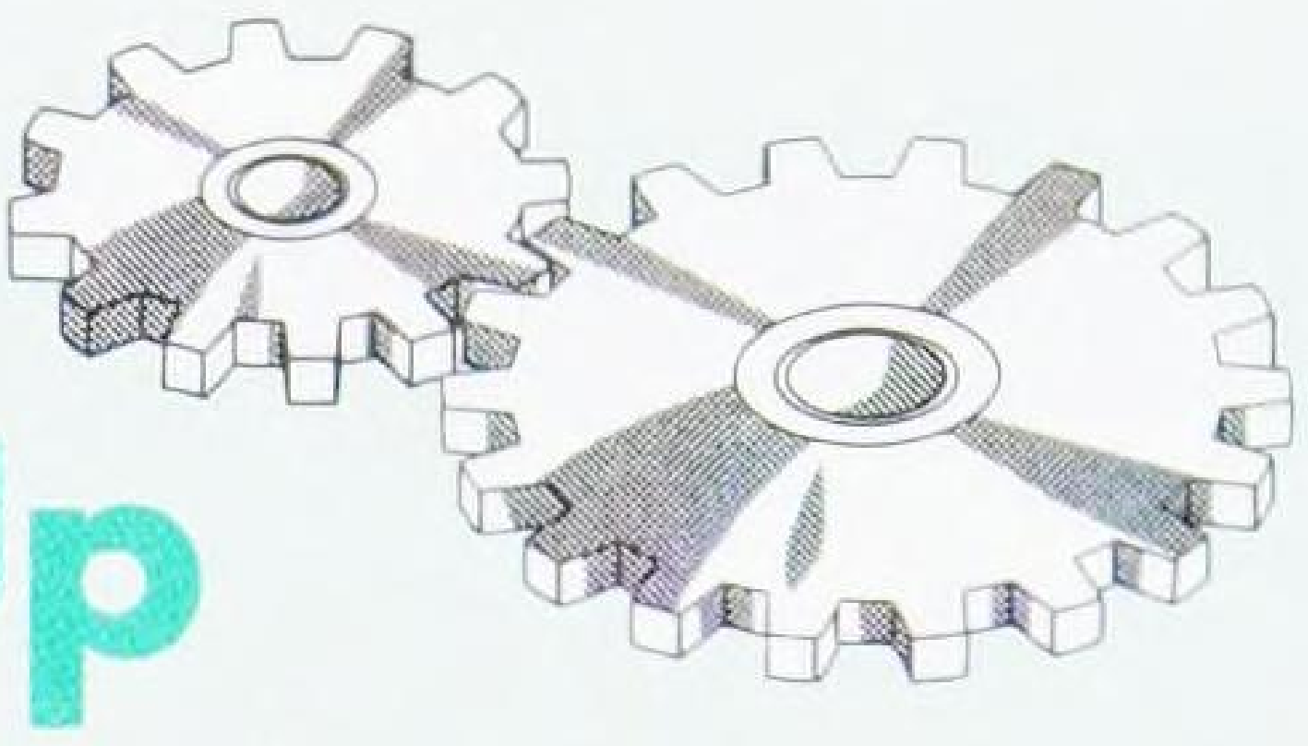
13 Introduction to Animals

Close your eyes and picture an animal. What comes to your mind? Did you imagine something with four legs and fur, or did you see an insect, a worm, or a person?

FIND OUT!

Do this simple activity to find out how different members of the Animal Kingdom are.

Look at the large photograph at the left. On a sheet of paper, make a *list* of all the animals you recognize in the photo. How many animals are on your list? Did you list five or six? Of course the human and the fish are animals, but so are the corals, sponges, and fanlike organisms. **In your Journal,** write a one sentence definition of the word "animal."



Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 13-1 What Is an Animal?
- Animal Characteristics
- Animal Classification

Section 13-2 Science and Society
Experiments Using Animals
- To Test or Not To Test

Section 13-3 The Simplest Invertebrates
- Sponges
- Origin and Importance of Sponges
- Cnidarians
- Origin and Importance of Cnidarians

Section 13-4 The Simple Worms
- Flatworms
- Roundworms

Previewing Science Skills

- In the **Skill Builders,** you will make a concept map, compare and contrast, and outline.
- In the **Activities,** you will observe, hypothesize, and collect data.
- In the **MINI-Labs,** you will observe, describe, hypothesize, experiment, and predict.

What's next?

Now that you know that there are many different types of animals, you will learn what makes them different and how they are classified. You will also learn about some invertebrates—sponges, cnidarians, and simple worms.

13-1 What Is an Animal?

New Science Words

vertebrates
invertebrates
radial symmetry
bilateral symmetry

Objectives

- Identify the characteristics of animals.
- Determine how the body plans of animals differ.
- Distinguish between invertebrates and vertebrates.

Animal Characteristics

If someone asked you if it was important to protect giant pandas to keep them from becoming extinct, you would probably say yes. But would you feel the same if you were asked about an endangered worm or beetle or spider? How are animals' relationships to each other and to us important? Let's look at the characteristics that all animals have in common.

1. Animals cannot make their own food. They depend on other living things in the environment for food. Some eat plants, some eat other animals, and some eat both plants and animals.
2. Animals digest their food. They can't use the proteins, fats, and carbohydrates in foods directly. Instead, food must be broken down into molecules small enough for their bodies to use.
3. Many animals move from place to place. Moving around lets them find food, escape from enemies, find a better place to live, and find mates. Animals that move very slowly or not at all, have adaptations that let them take care of these needs.
4. Animals have many cells. Different cells carry out different functions such as digesting food, reproduction, and getting rid of wastes.
5. Animal cells are eukaryotic. They have a nucleus surrounded by a membrane and organelles surrounded by membranes.

Figure 13-1. Animals depend on other living things for their food.

An animal is a many-celled eukaryotic organism that must find and digest its food. How does this description compare with the one you wrote for the activity on page 301?

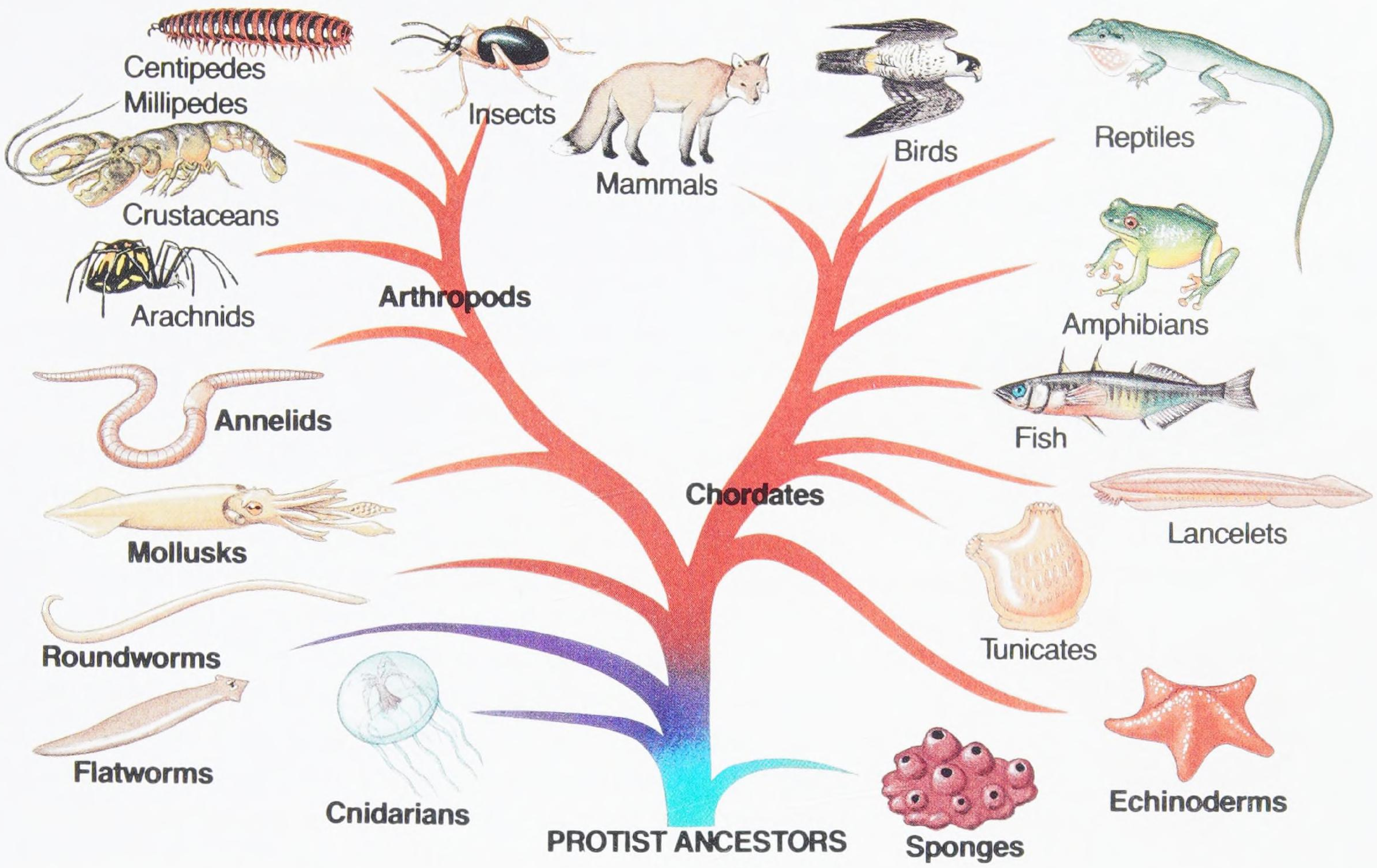

Centipedes
Millipedes
Insects
Mammals
Birds
Reptiles
Crustaceans
Arachnids
Arthropods
Amphibians
Annelids
Fish
Chordates
Lancelets
Mollusks
Tunicates
Roundworms
Flatworms
Cnidarians
Echinoderms
PROTIST ANCESTORS
Sponges

Figure 13-2. This diagram shows the relationships between different groups in the animal kingdom.

Animal Classification

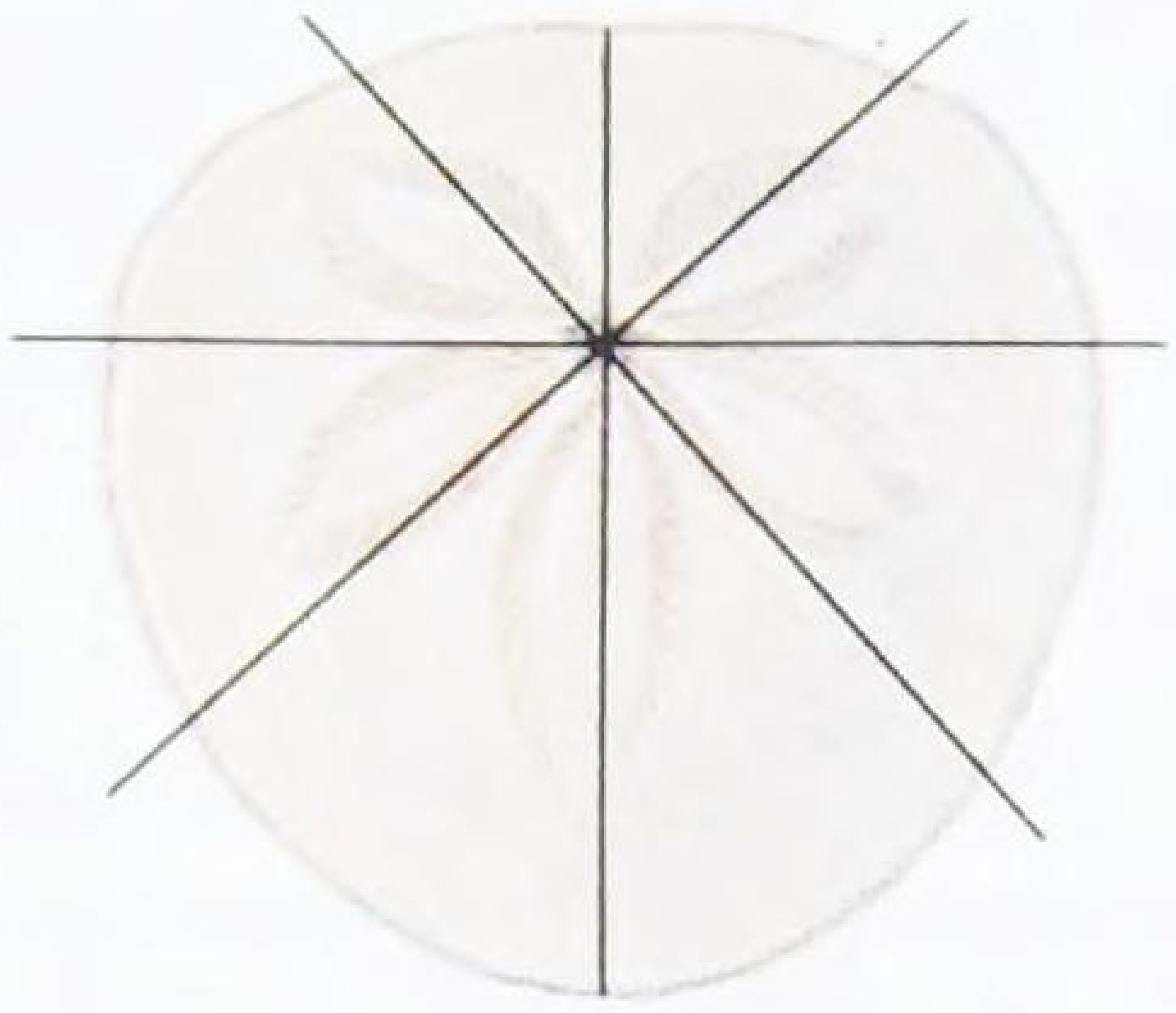
Scientists have identified and named over one million species of animals. They think there may be as many as three million more to identify and name. There are nine major phyla in the animal kingdom. The phyla are shown in Figure 13-2. All animals have the characteristics listed on page 302, but when a scientist comes across a new animal, how does he or she begin to classify it?

The first thing the scientist will do is look to see if the animal has a backbone. Animals with backbones are called **vertebrates.** Some vertebrate animals are fish, humans, whales, and snakes. About 97 percent of all other animal species are invertebrates. **Invertebrates** are animals that don't have a backbone. Sponges, jellyfish, worms, insects, and clams are all invertebrates.

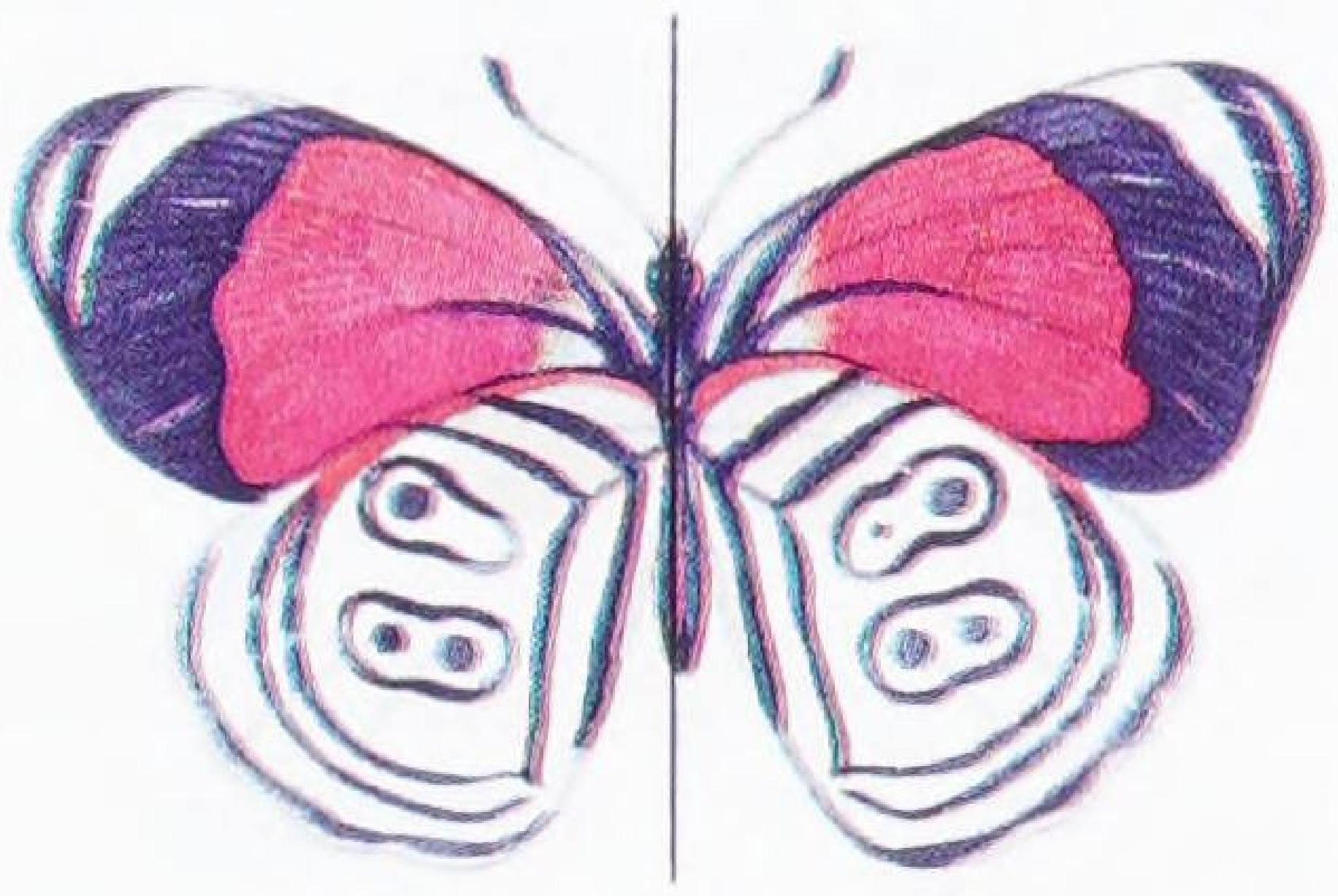
The next thing the scientist will look at is the arrangement of the animal's body parts. This is called the animal's symmetry. Some animals have body parts arranged in a circle around a central point, the way spokes are arranged around the hub on a bicycle wheel. These animals have **radial symmetry.** Hydra, jellyfish, and sand dollars have radial symmetry.

Connect to... Chemistry

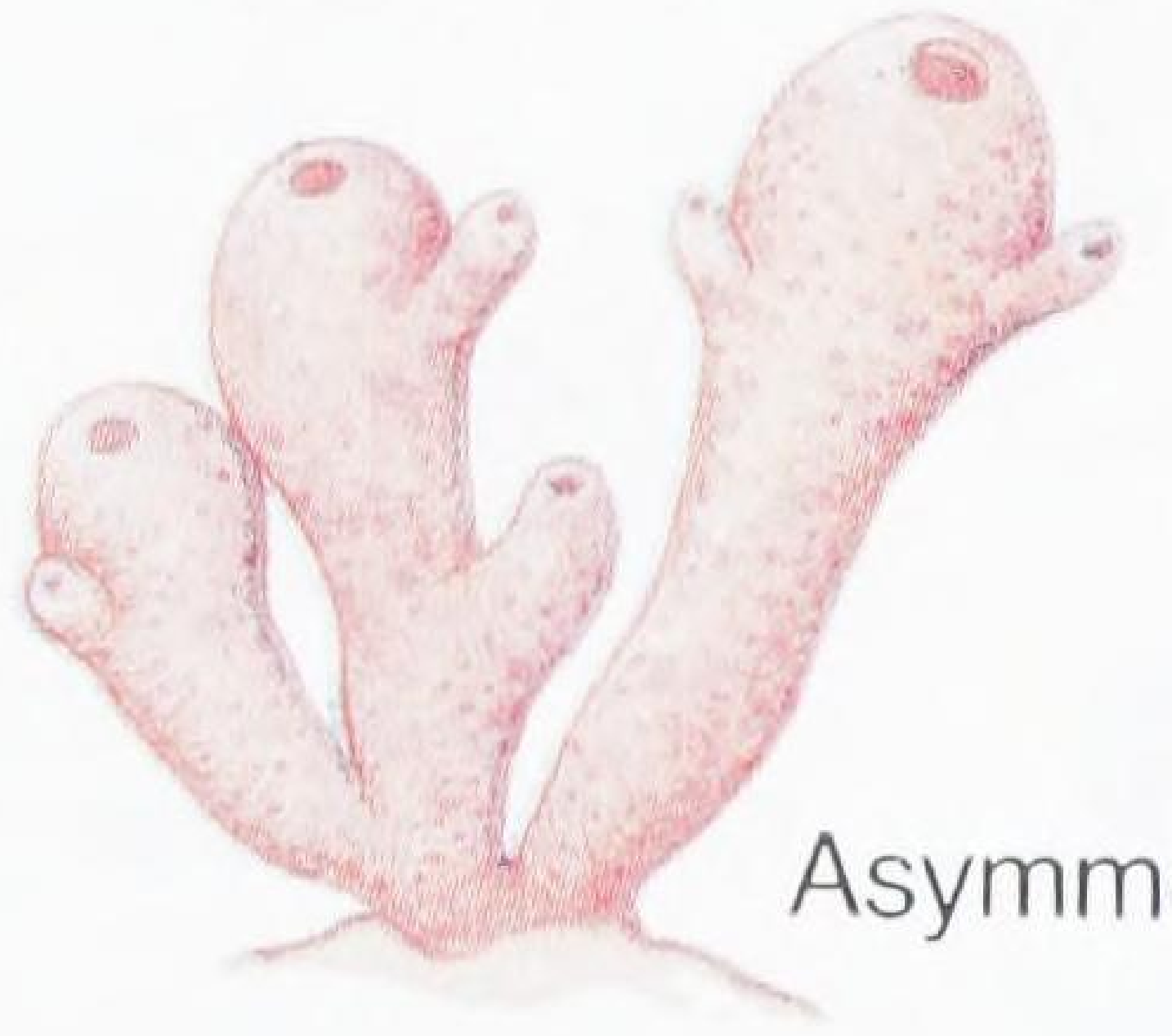
Among vertebrates, there are several groups of fish including cartilage fish and bony fish. Find out what elements the skeleton of a bony fish contains that cartelagenous skeletons don't have.



Radial symmetry



Bilateral symmetry



Asymmetry

Figure 13-3. Sand dollars have radial symmetry, butterflies have bilateral symmetry, and sponges are asymmetrical.

Most animals have bilateral symmetry. Look in the mirror. Does your body look the same on both sides? An animal with **bilateral symmetry** has its body parts arranged in the same way on both sides of its body. In Latin the word *bilateral* means "two sides." Bilateral animals can be divided into right and left halves by drawing an imaginary line down the length of the body. Each half is a mirror image of the other half.

Animals with bilateral symmetry have a definite front, or *anterior,* end. They also have a definite back, or *posterior,* end. The upper side of the animal is called the *dorsal* side, and the lower side is called the *ventral* side.

Some organisms have no definite shape and are called asymmetrical. There is no way their bodies can be divided into matching halves. Many sponges are asymmetrical. The three types of symmetry are shown in Figure 13-3.

When the scientist has determined an animal's symmetry and whether it's an invertebrate or vertebrate, he or she will have to identify characteristics it has in common with other animal groups in order to classify it. You learned in Chapter 6 that animals in a group have similar characteristics because they descended from a common ancestor. The evolutionary history and relationships among animal phyla are represented by the diagram in Figure 13-2. It shows what are thought to be some of the major developments in animal evolution that led to the diversity we see today.

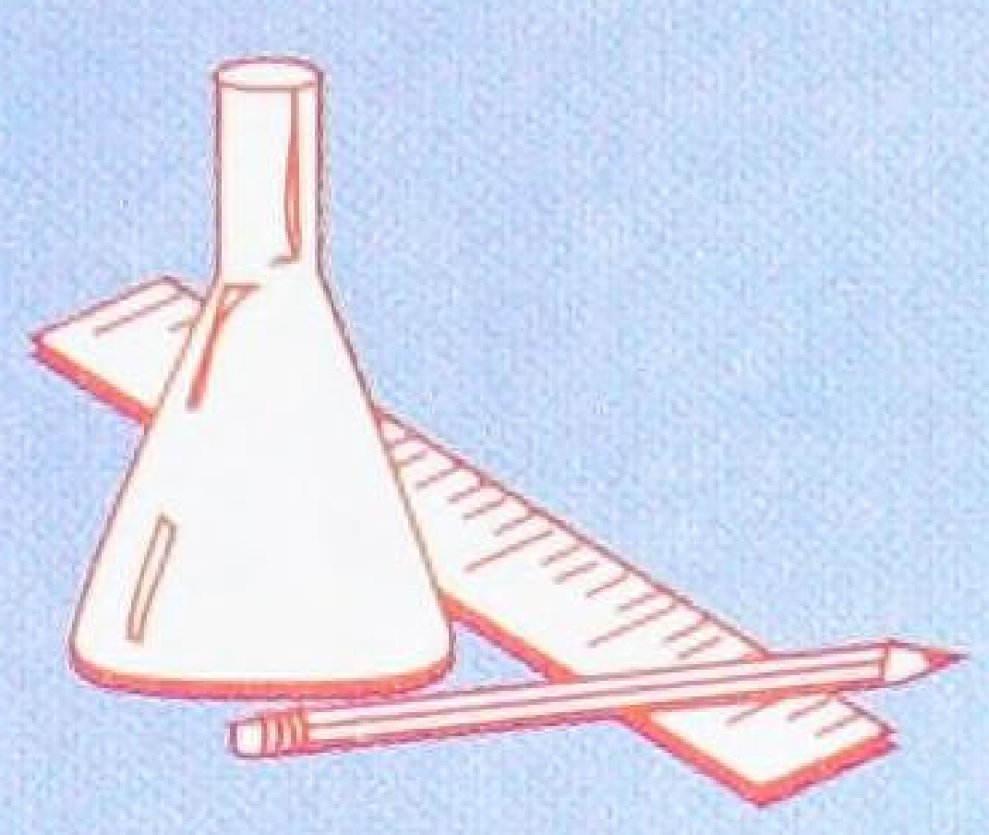
SECTION REVIEW

1. What are five characteristics of animals?
2. What are the types of symmetry? Give examples.
3. How are invertebrates different from vertebrates?
4. **Apply:** Identify your dorsal and ventral sides and your anterior and posterior ends.
5. **Connect to Earth Science:** Find out what kind of rock most fossil animals have been found in. How is this rock formed?

Skill Builder

Concept Mapping

Using the information on pages 303 and 304, make an events chain concept map showing the steps a scientist might use to classify a new animal. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.



ACTIVITY 13-1

Determining Symmetry

Problem: *What type of symmetry do some animals have?*

Materials

- paper and pencil

Procedure

1. *Observe* each animal pictured on this page. Decide if the animal has radial symmetry, bilateral symmetry, or does not have symmetry.
2. Record your answers in the data table. If you need help, refer to Section 13-1.
3. Explain how you decided what type of symmetry each animal has in the column labeled "Reason."

Data and Observations

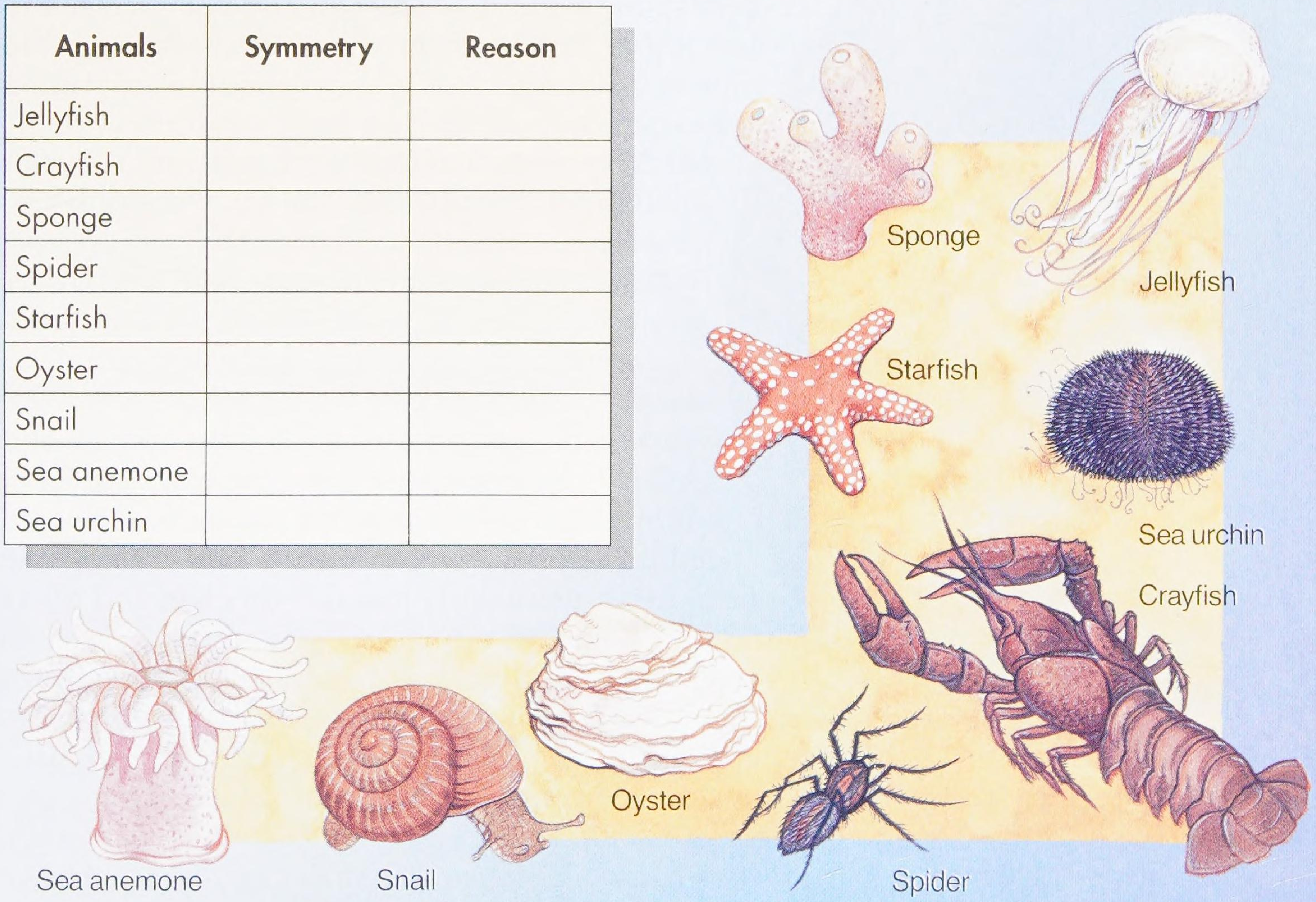
Animals	Symmetry	Reason
Jellyfish		
Crayfish		
Sponge		
Spider		
Starfish		
Oyster		
Snail		
Sea anemone		
Sea urchin		

Analyze

1. Which animals have radial symmetry?
2. Which animals have bilateral symmetry?
3. Which animal has no symmetry?
4. If an animal has an anterior and a posterior end, what kind of symmetry does it have?

Conclude and Apply

5. Based on your observations, *predict* what advantages radial symmetry might give an animal.
6. *Predict* the advantages of bilateral symmetry.
7. How does type of symmetry *relate* to characteristics of each animal phylum?



SCIENCE & SOCIETY

13-2 Experiments Using Animals

Objectives

- Acknowledge the advancements made due to experimentation with animals.
- Develop an idea for a compromise between progress in medicine and the welfare of laboratory animals.

To Test or Not To Test

Did you know that you're probably alive today because of laboratory animals? You may have received a shot of penicillin or a flu vaccine. Such vaccines have wiped out diseases such as polio and smallpox in the United States. Malaria, caused by a microscopic parasite, has killed more people in the world than any other disease. In order to develop an anti-malarial medicine, canaries were infected with malaria to allow scientists to learn more about the parasite. In fact, every surgical technique and drug used today was first tried in animals. But what about the animals? Is it truly necessary to experiment on animals?

It is estimated that each year about 100 million animals are used for research, education, or product testing. Cats are used to learn about the dangerous effects of drug addiction. Digestive enzymes are taken from pig digestive systems and used to help people with cystic fibrosis digest food. Antibiotics are first tested on rats before they are tried on humans. Organ transplants are possible because surgeons first practice on cows and other animals. Dogs and rabbits were used to understand diabetes and in the discovery of insulin. Treatments for cancer, alcoholism, and heart disease have all been greatly improved through experimentation using animals. Due to the advancements in medicine resulting from experiments with animals, a baby born today has a much greater chance of living to a very old age than ever before in the history of the world.

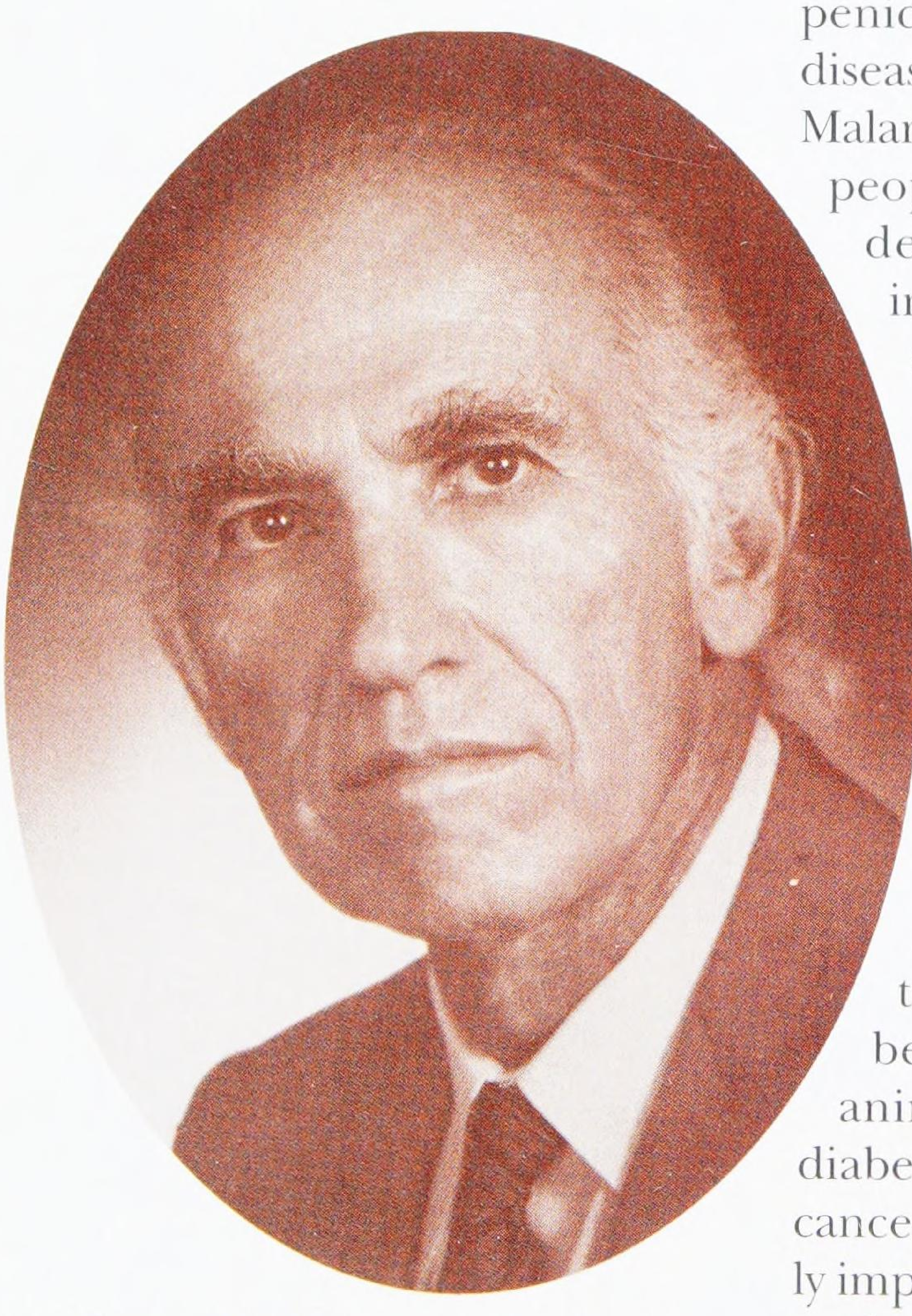


Figure 13-4. Jonas Salk developed the vaccine for polio that underwent much testing before it was made available for people.

Today animal rights activists are fighting for the rights that they say animals are entitled to. There are about 10 million people in the United States who belong to animal rights groups. It's not just the deaths of animals that they are concerned with. Many are opposed to the conditions in which the lab animals are kept. Others feel that dissections of cats, frogs, pigs, and other animals by school-age students are unnecessary.

Some of the tests performed on the animals are very painful. In one experiment, dogs were fed pesticides until they were so sick they could not move. Some reforms are in progress. One of the most common tests for irritancy is the Draize test. In this test, high concentrations of the substance being tested are squirted into the eyes of rabbits. Many companies are looking for alternatives to this test and are reducing the concentrations of test substances. Researchers think that saving human lives through research is more important than the animal lives that are sacrificed. They feel that reforms and regulations may threaten the future of science.

The controversy will surely go on for years. Perhaps a compromise of some type will be reached. Activists often acknowledge the importance of these experiments and argue that only those that are necessary should be allowed. But where can we draw the line? Often basic research that appears unnecessary is later shown to be very important in solving a new medical problem. Will a solution ever be reached? Although animal research has saved many lives, pain and distress for the animals often results in their death.

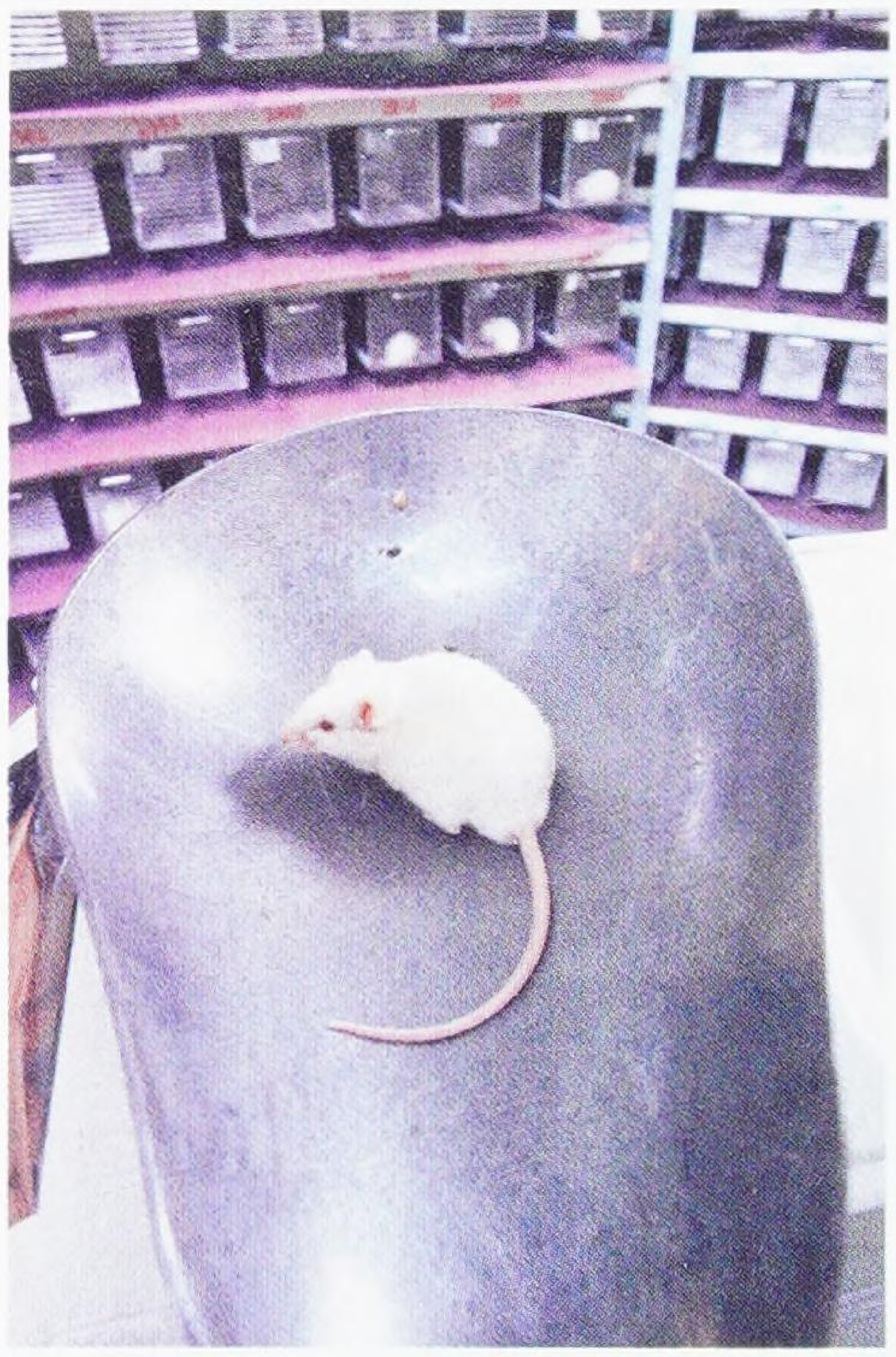


Figure 13-5. Many animals are kept in laboratories and used for research.

SECTION REVIEW

1. Name three diseases for which treatments have been greatly improved due to research using animals.
2. What is the basic belief of animal rights groups?

SCIENCE & SOCIETY

You Decide!

You have your heart set on a brand new pair of acid washed jeans. Before you go to buy them, you hear on the news that the company that makes your favorite brand uses animals in experiments. To determine if it would irritate humans, the company tests the bleach solution used to lighten the jeans on the eyes and skin of animals. Knowing this, would you still buy the jeans?

13-3 The Simplest Invertebrates

New Science Words

sessile
Porifera
filter feeders
collar cells
regeneration
hermaphrodite
larva
cnidarians
tentacles
polyp
medusa

Objectives

- Identify the structures that make up sponges and cnidarians.
- Describe how sponges and cnidarians obtain food and how they reproduce.

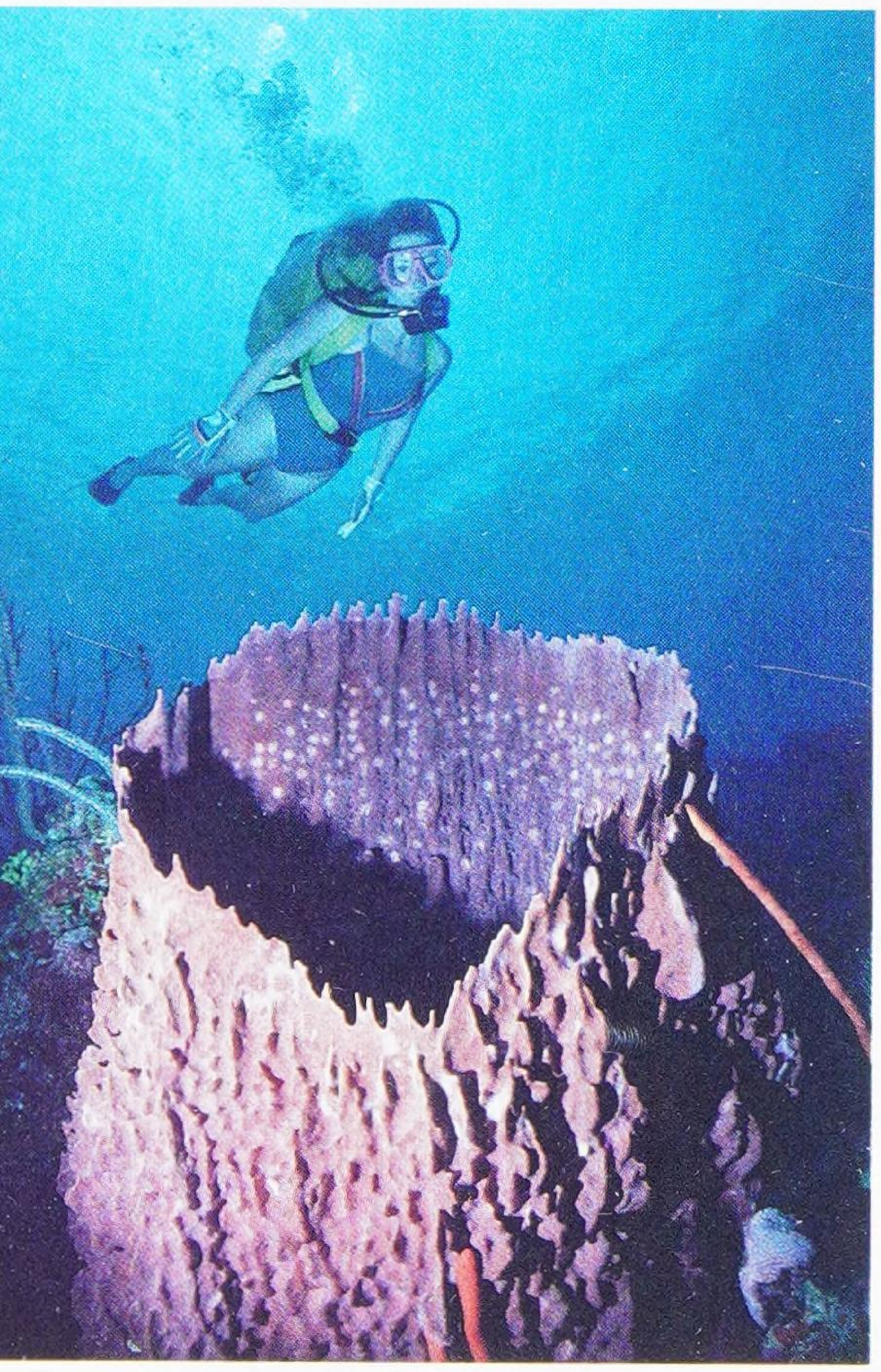


Figure 13-6. Some species of sponge can grow to be larger than humans.

Sponges

Let's take a closer look at the different animal phyla. The "simplest" of the animal groups are sponges, cnidarians (ni DAIR ee uhnz), and simple worms.

Does the sponge in Figure 13-6 look like an animal to you? Well, it is. Years ago, early scientists thought sponges were plants. However, sponges make up the group of animals considered to be the simplest in the animal kingdom. They have simple body plans and no body tissues, organs, or organ systems.

All sponges live in water. Most are found in warm, shallow salt water near the coast, although some grow almost 1000 meters deep in the ocean. A few species live in freshwater rivers, lakes, and streams. Sponges grow in many shapes, sizes, and colors. Some have radial symmetry, but most are asymmetrical. They may be smaller than a marble or larger than a compact car!

Adult sponges live attached to one place. They are often found with other sponges in colonies that never move, unless they are washed away by a strong wave. Organisms that remain attached to one place during their lifetime are **sessile.** Early scientists classified sponges as plants because they didn't move. As microscopes were improved, scientists observed that sponges couldn't make their own food, and so they reclassified them as animals.

The body of a sponge is covered with many small openings called pores. It is from the pores that sponges get their phylum name, **Porifera.** Porifera comes from a Latin word meaning "pore-bearing."

Figure 13-7 shows the body plan of a sponge. A sponge's body is a hollow tube closed at the bottom but with an opening in the top. The body wall has two cell layers made up of several different types of cells. There are cells that help a sponge get food, cells that digest food, cells that carry nutrients to all parts of the sponge, and cells that enable water to flow into the sponge.

How do filter feeders obtain food?

Sponges obtain food from water that is pulled in through their pores. They filter bacteria, algae, protozoans, and other materials out of the water. Organisms that obtain food this way are called **filter feeders.** Cells that line the inside of the sponge, called **collar cells,** help water move through the sponge. You can see in Figure 13-7 that collar cells have flagella. The beating of the flagella in these cells brings water into the sponge. The water moving through the sponge also brings oxygen to the cells and carries away wastes.

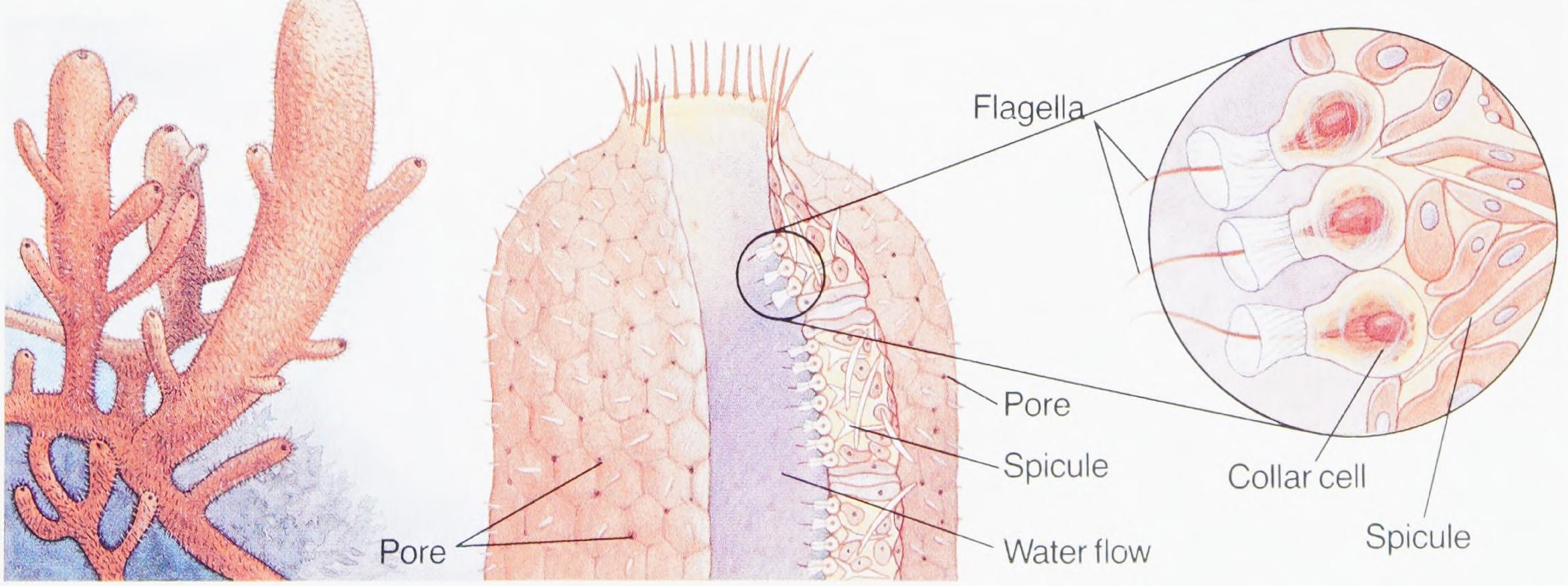
Connect to...
Chemistry

Ocean water contains many dissolved elements. Spicules of "glass" sponges are composed of silica. Other sponges have spicules of calcium carbonate. *Relate* the composition of spicules to the composition of seawater.

The bodies of many sponges are made of sharp, pointed structures called spicules. The soft-bodied sponges people use to take baths or to wash their cars have a skeleton of a fibrous material called spongin. Other sponges are supported by both spicules and spongin. Scientists classify sponges based on the kind of material that makes up their skeleton.

Sponges reproduce both asexually and sexually. Sponges can reproduce asexually by forming buds. New sponges can also form from small pieces that break off the parent sponge. Sponge growers actually cut sponges into pieces, attach weights to them, and put them back into the ocean so the sponges can regenerate. **Regeneration** is the ability of an organism to replace body parts.

Figure 13-7. Sponges are made of several different types of specialized cells. The spicules provide structure for the sponge.



Sponges can reproduce sexually by egg and sperm. Some species of sponges have separate sexes, but most are hermaphrodites. A **hermaphrodite** (hur MAF ruh dite) is an animal that produces both sperm and eggs. Sperm are released in the water and carried by currents to other sponges where they fertilize the eggs. The fertilized egg develops into a young organism called a **larva.** Larvae usually look very different from adults. Sponge larvae have cilia that swim about in the water. After a short time, the larva settles down on an object. There it will remain and grow into an adult sponge.

Origin and Importance of Sponges

Sponges appeared on Earth about 600 million years ago in the Cambrian period. Their collar cells are similar to a type of colonial protozoan that is thought to be the ancestor of sponges. No other animal species is known to have evolved from sponges.

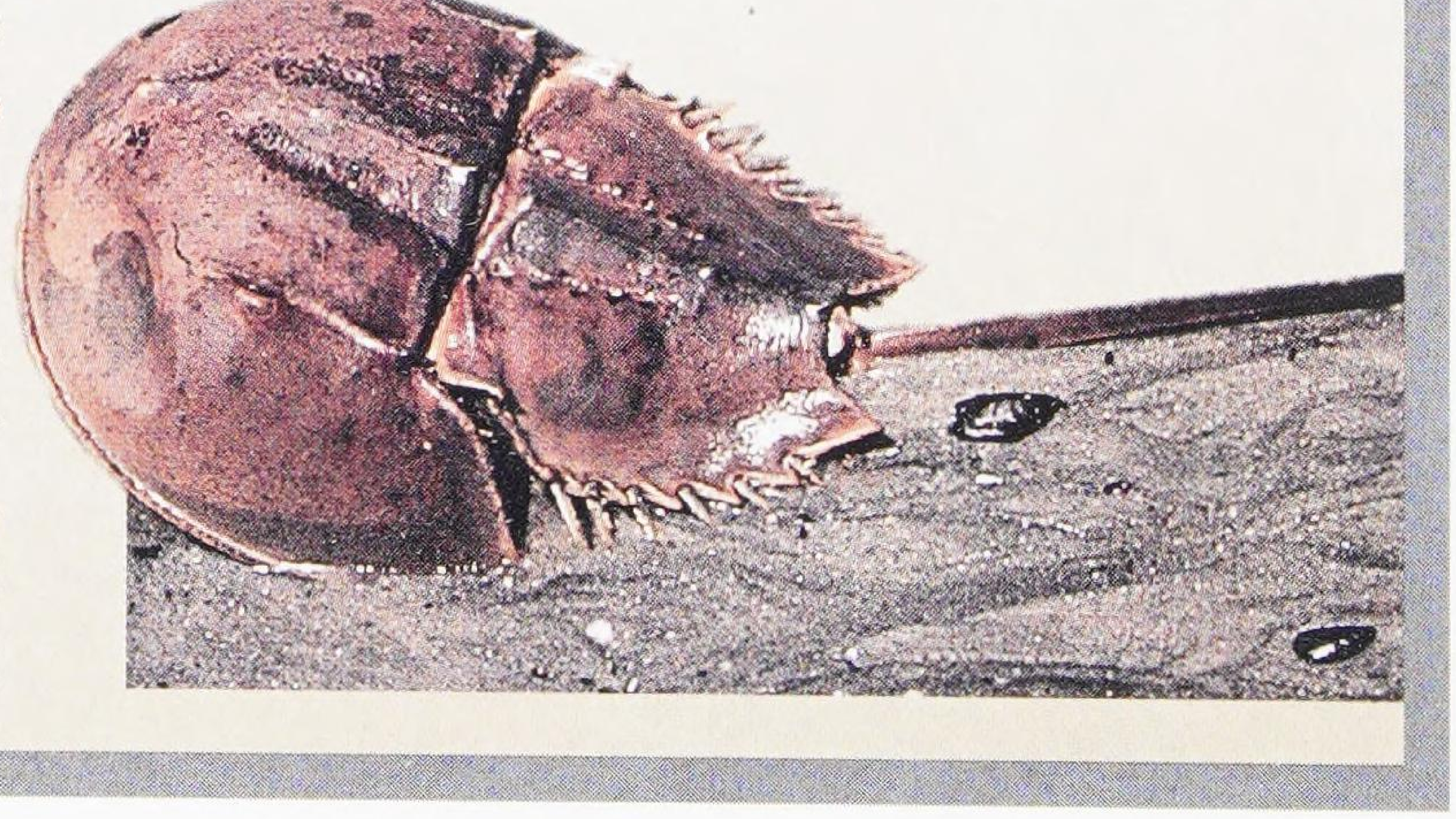
TECHNOLOGY

Sea Pharmacy

Eighty percent of all life on Earth lives in the sea. Scientists hope that the 400 000 or more species of ocean plants and animals will provide chemicals to produce new medicines. But with 400 000 plus species, where do scientists start looking? One place is in organisms that use chemicals for protection such as sponges, soft corals, and sea squirts. These chemicals may one day be useful to humans. Sea specimens are also tested for the ability to stimulate the human immune system or to limit the growth of bacteria, viruses, or tumors.

There are many promising leads. The blue blood of horseshoe crabs is used extensively to test for the presence of bacteria that cause infectious diseases. One rare sponge called *Luffariella variabilis* contains a chemical that blocks pain and inflammation, and may be used for patients with arthritis and muscular dystrophy. Algae, sponges, and sea squirts have provided potential anticancer drugs. Poison from puffer fish may one day be used as an anesthetic.

Think Critically: Why are drugs from the sea just beginning to be thoroughly researched?



Sponges provide food for many fish, snails, and starfish. They are shelter for smaller organisms that live in their bodies. Natural sponges are used in pottery, painting, in other arts and crafts, and as bath sponges. Researchers are collecting and testing sponges as possible sources of medicines.

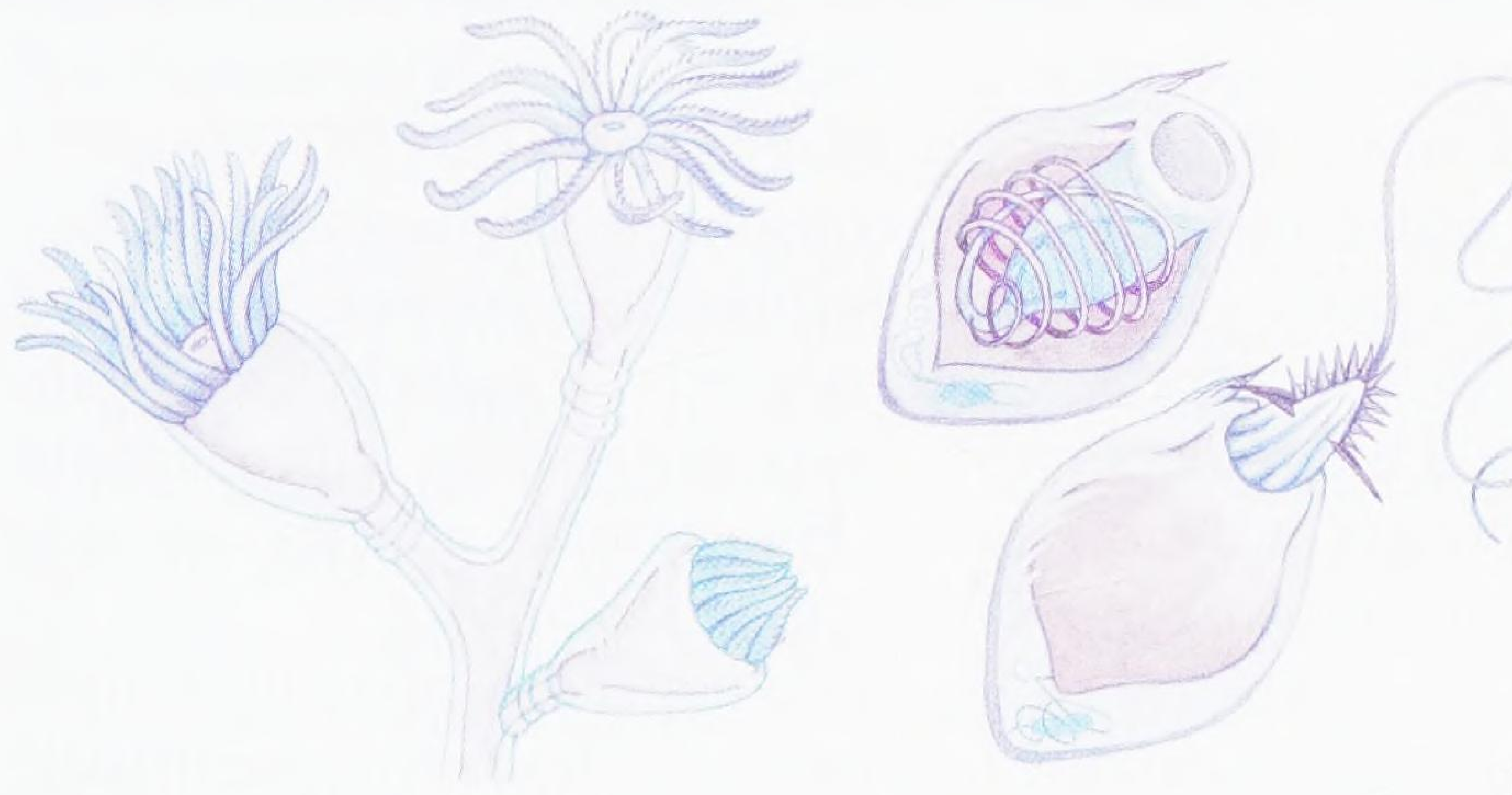

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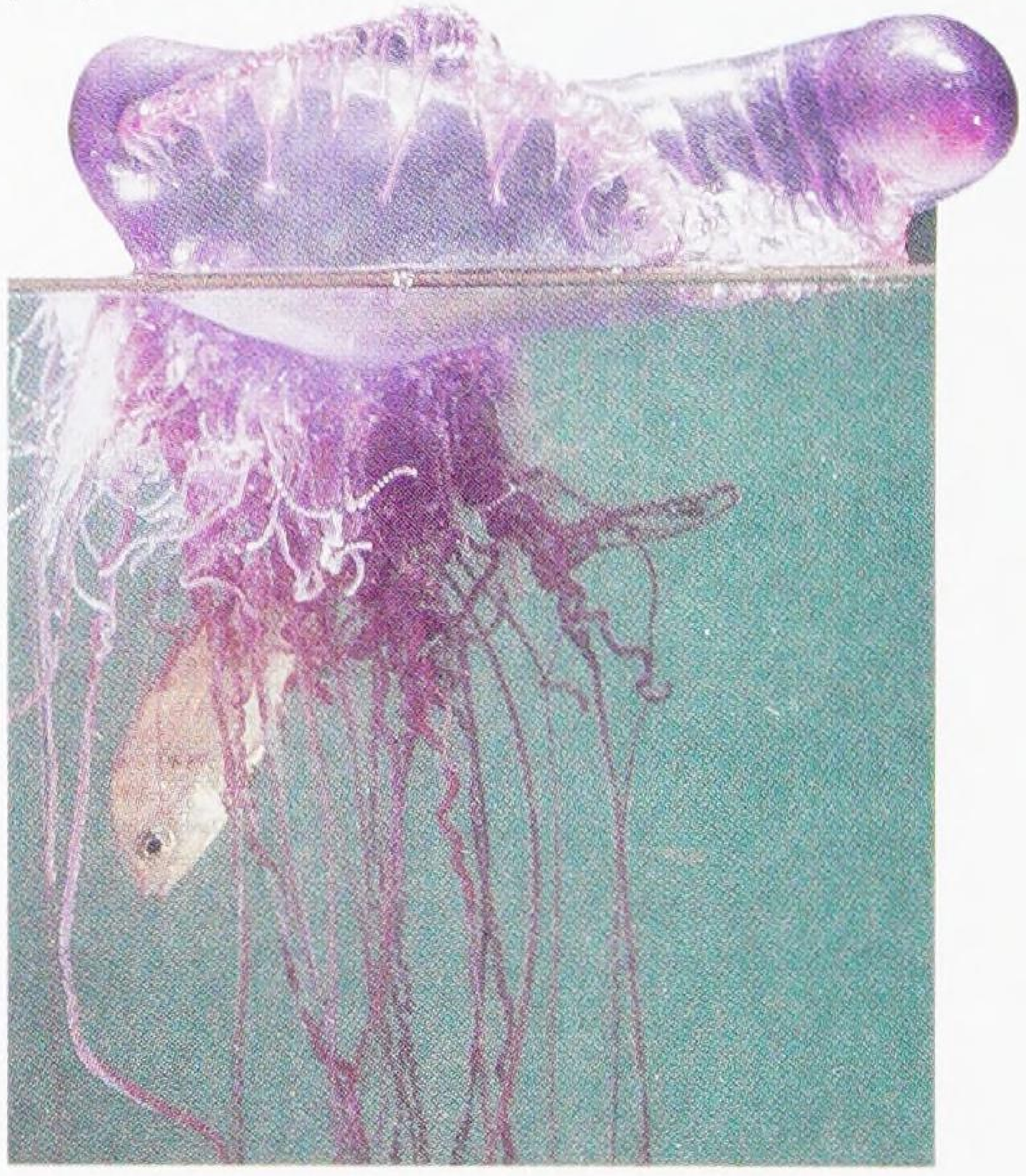
Figure 13-8. The polyp colony (a), Portuguese man-of-war (b), and sea anemone (c) all contain stinging cells characteristic of the phylum Cnidaria.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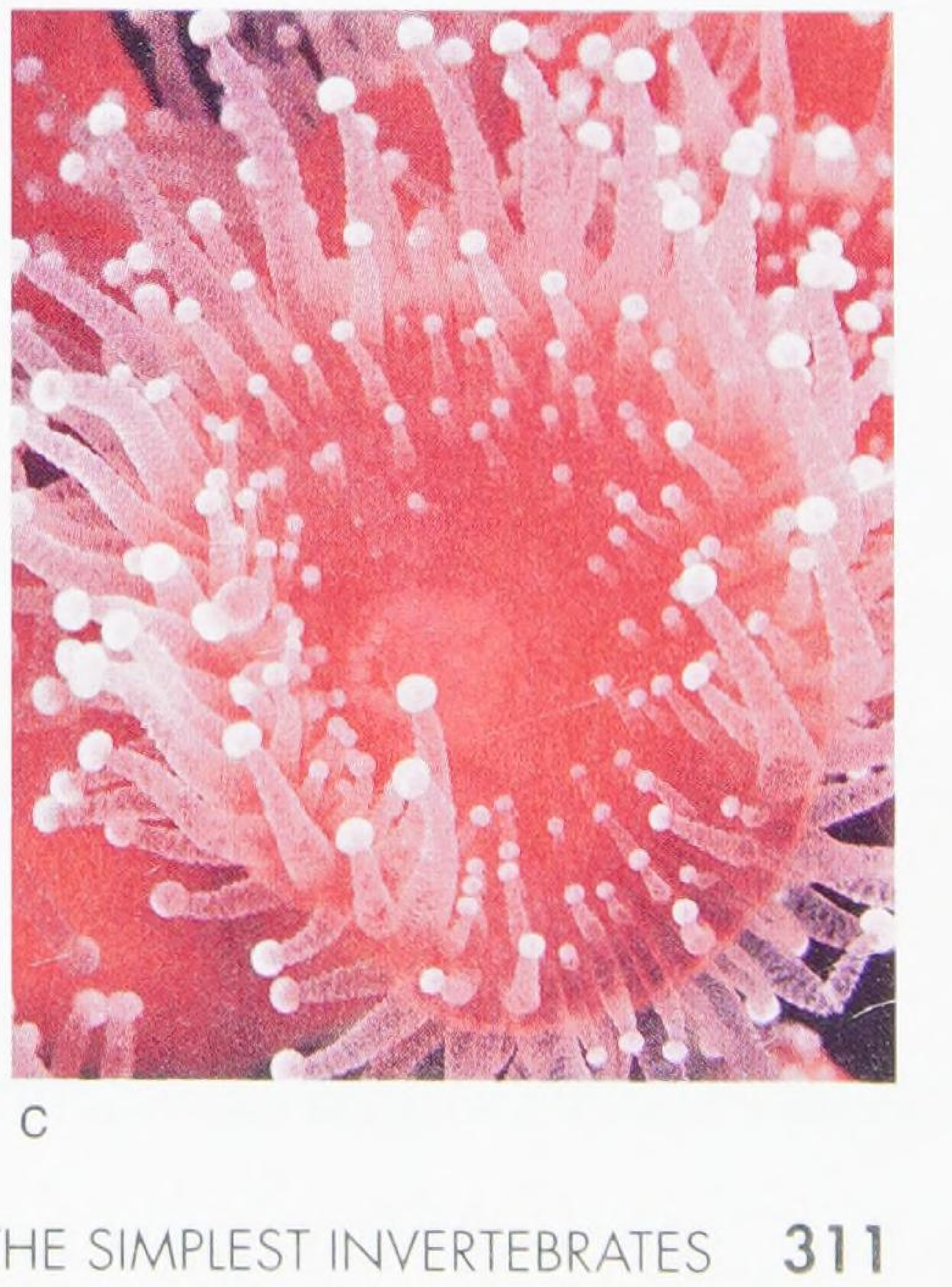
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Cnidarians

The iridescent Portuguese man-of-war, colorful sea anemone, and hydra you see in Figure 13-8 belong to a group of animals called **cnidarians.** This name describes the stinging cells that all members of this phylum have. The word *cnidaria* is Latin for "stinging cells."

Although many types of hydra live in fresh water, most cnidarians live in salt water. Cnidarians live as single organisms and in colonies. All cnidarians have radial symmetry and bodies more complex than those of sponges. They have two cell layers that are arranged into tissues. Cnidarians have a digestive cavity where food is broken down. Most cnidarians are adapted with armlike structures called **tentacles** that surround the mouth. The tentacles are armed with the stinging cells that help the organism capture food.

The stinging cell of a cnidarian is actually a capsule or sac that contains a coiled harpoonlike thread and poison. Each capsule has a hair that works like a trigger. When a small organism bumps into the hair, the capsule explodes and shoots out its thread and poison. The poison paralyzes the organism until the tentacles wrap around it to pull it into the mouth. In most species, food is digested by enzymes in the digestive cavity. Undigested materials leave through the mouth.

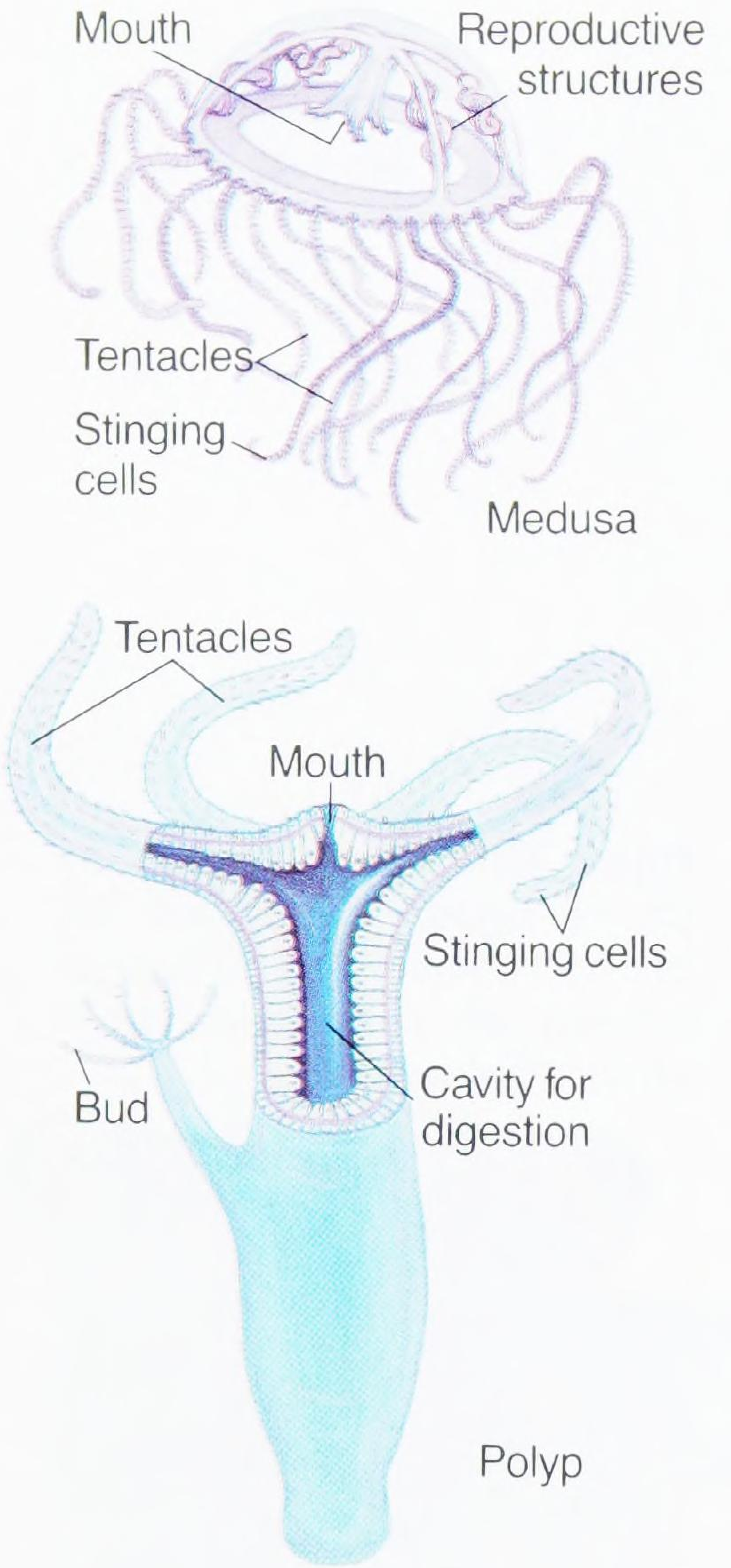


Figure 13-9. The polyp form and medusa form are the two body plans of cnidarians.

Cnidarians have two different body plans. Figure 13-9 shows the two body plans. The **polyp** is shaped like a tube or vase and is usually sessile. The **medusa** is bell-shaped and free swimming. Some cnidarians go through both polyp and medusa stages during their life cycles.

The Portuguese man-of-war on page 311 is really a colony of polyps. Some of these polyps gather food, and others are used for reproduction. The man-of-war is adapted with a large, blue, gas-filled float that is used like a sail and moves the colony through the water.

Cnidarians don't have complex nervous systems. They have a system of nerve cells called a nerve net. The nerve net carries impulses and connects all parts of the organism. This makes cnidarians capable of some simple responses and movements. For example, a hydra can somersault away from a threatening situation.

Cnidarians reproduce asexually and sexually. Polyps reproduce asexually by producing buds that eventually fall off the parent and grow into new polyps. Polyps can also reproduce sexually by producing either an egg or sperm. Sperm are released into the water and fertilize the eggs.

Medusa forms of cnidarians have both an asexual stage of reproduction and a sexual one. You can see the cycling between these two stages in Figure 13-10. Free-swimming medusae produce eggs and sperm and release them into the water. The eggs are fertilized and grow into larvae. The larvae eventually settle down and grow into polyps. Young medusae bud off the polyp and the cycle begins again.

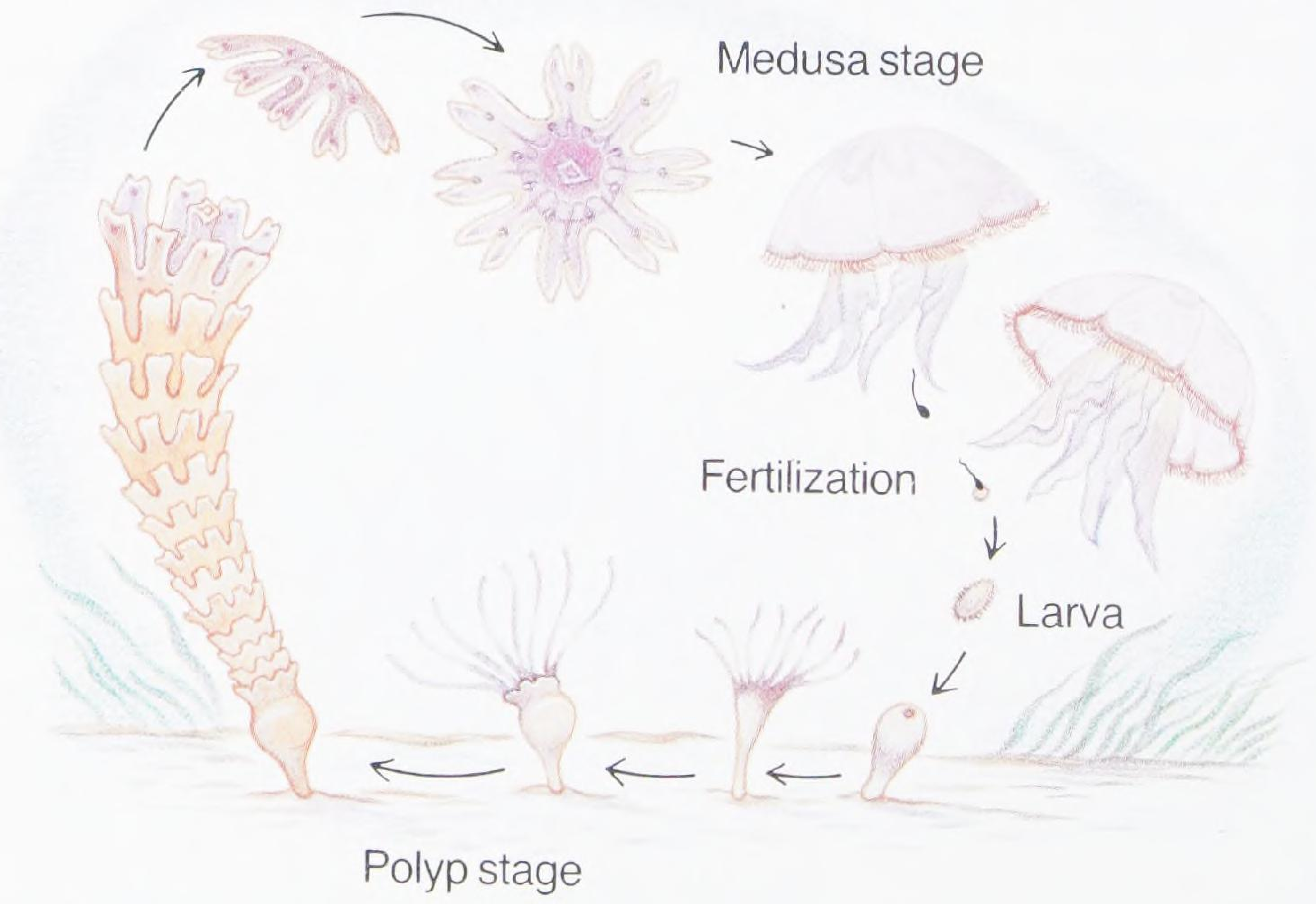
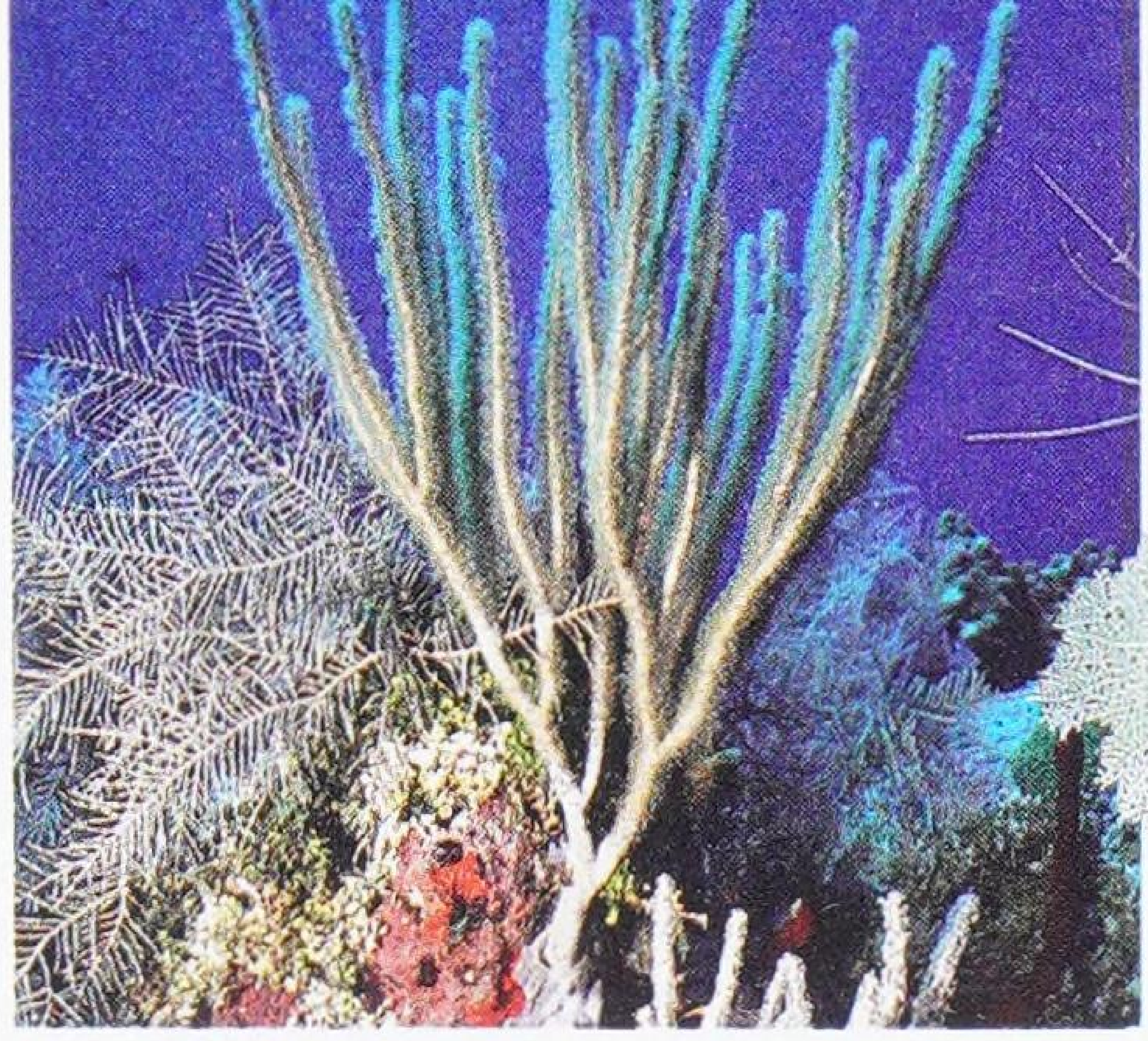


Figure 13-10. Some cnidarians alternate between polyp and medusa forms in their life cycles.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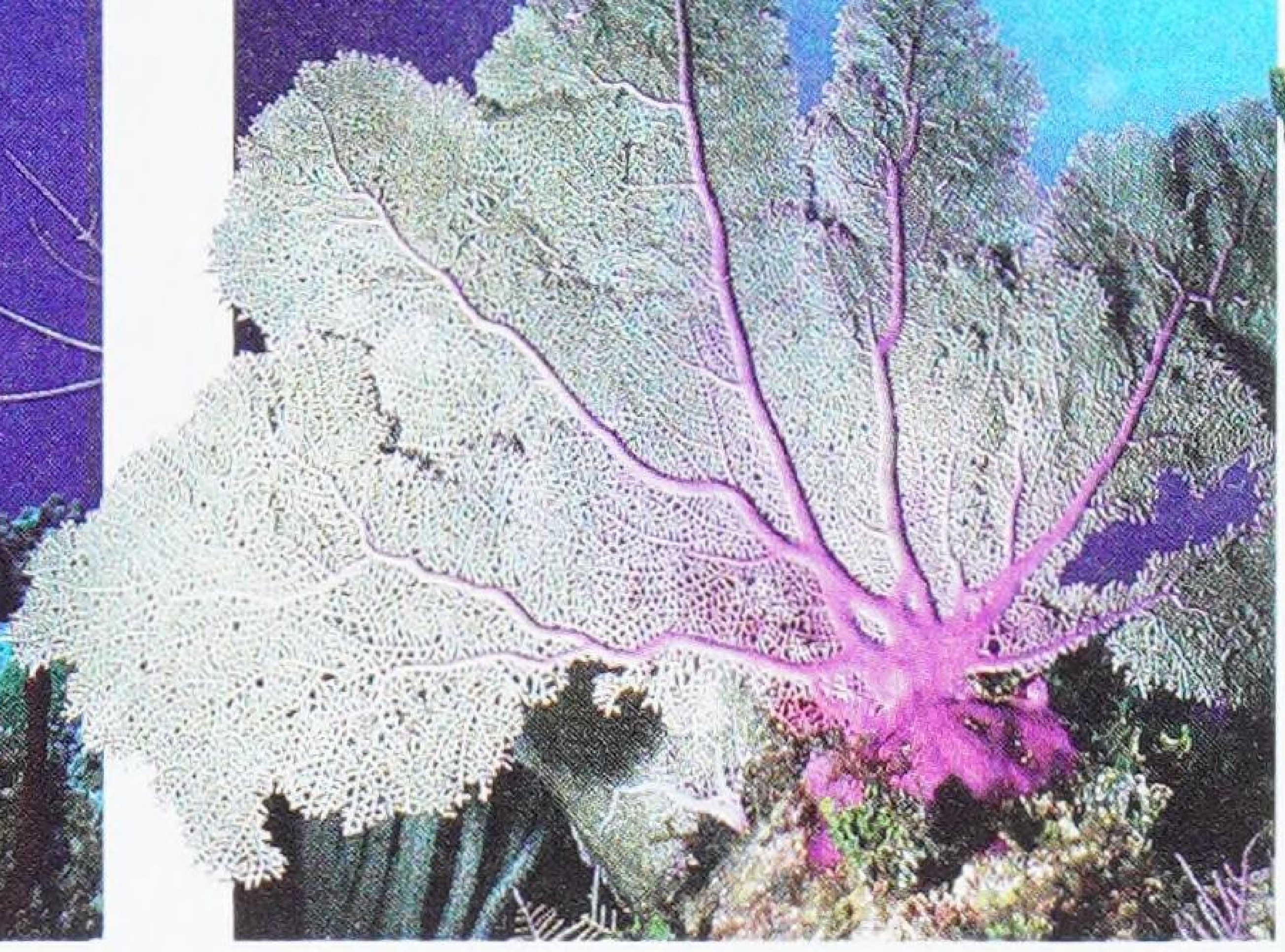
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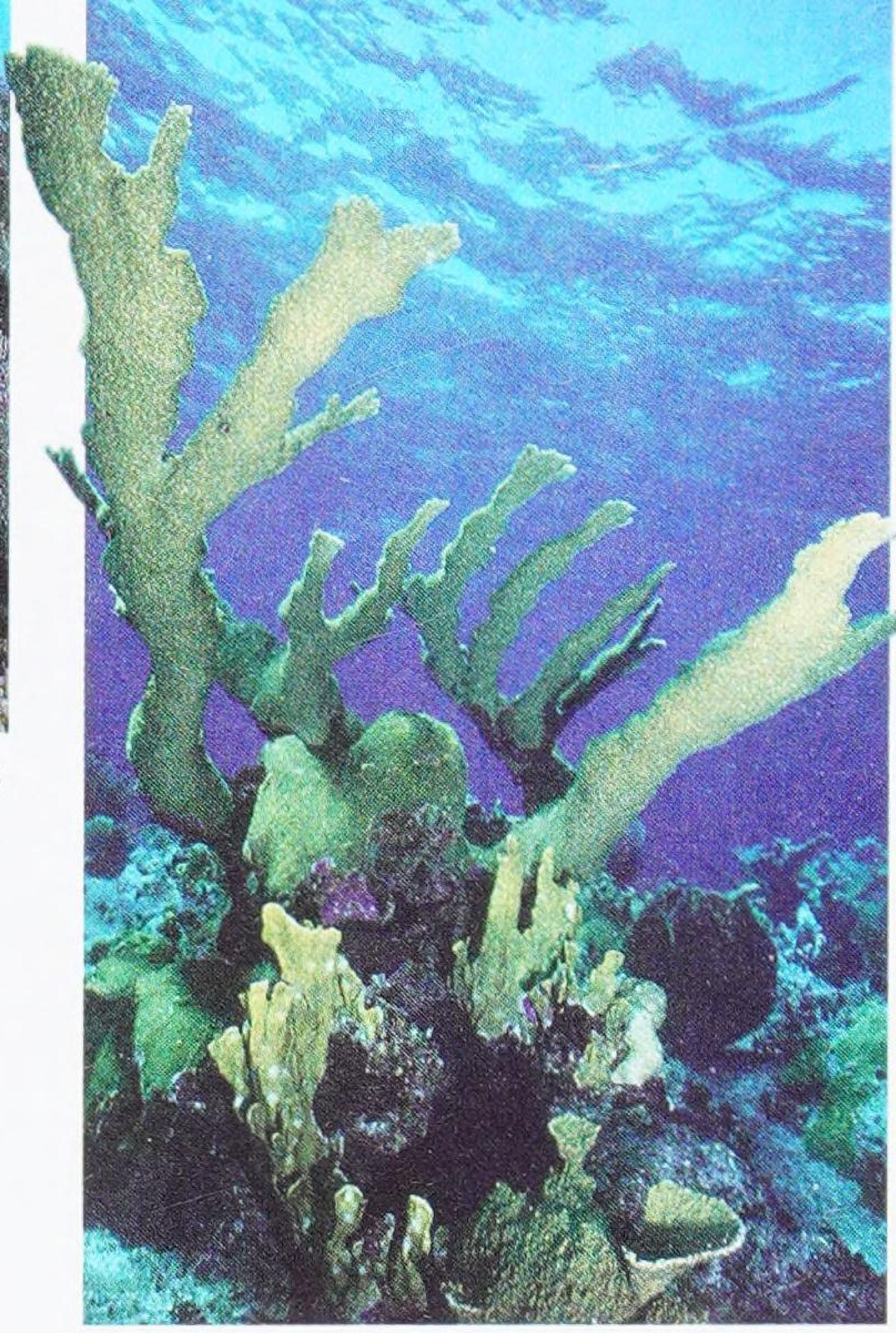
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Figure 13-11. Sea rods (a), sea fans (b), and elkhorn coral (c) are all cnidarians that help build coral reefs.

Origin and Importance of Cnidarians

Cnidarians were present on Earth during the Precambrian Era over 600 million years ago. Scientists think that the first form of cnidarian was the medusa. Polyps may have formed from larvae of medusae that became permanently attached to a surface. Most of the cnidarian fossils found are fossils of corals.

Corals are cnidarian polyp colonies that secrete a hard skeleton around themselves. Many of these polyps living together form coral heads of many different shapes. Some are round, and others look like antlers of elk or deer. Many coral heads together form large coral reefs near shores in warm tropical waters. A large variety of fish and other organisms live on coral reefs. Food and shelter are provided for these organisms in the reef.

Coral reefs protect beaches and shorelines from being washed away by ocean waves. The reefs are also areas of recreation for many people. The beautiful corals and large variety of sea life provide scuba divers and snorklers with a wonderful view of life-forms in a reef.

In Your JOURNAL

Imagine your class is planning a field study trip to the ocean. **In your Journal,** write a section for a student handbook to explain how to deal with jellyfish.

SECTION REVIEW

1. Compare how cnidarians and sponges obtain food.
2. Describe the two body plans of cnidarians and their forms of reproduction.
3. **Apply:** Why are most fossils of cnidarians coral fossils? Would you ever find a fossil sponge? Explain.
4. **Connect to Earth Science:** Find out what a coral barrier reef is, and what an atoll is.

Comparing and Contrasting

Skill Builder

Compare and contrast the methods of getting food in sponges and cnidarians. If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.

ACTIVITY 13-2

Observing a Cnidarian

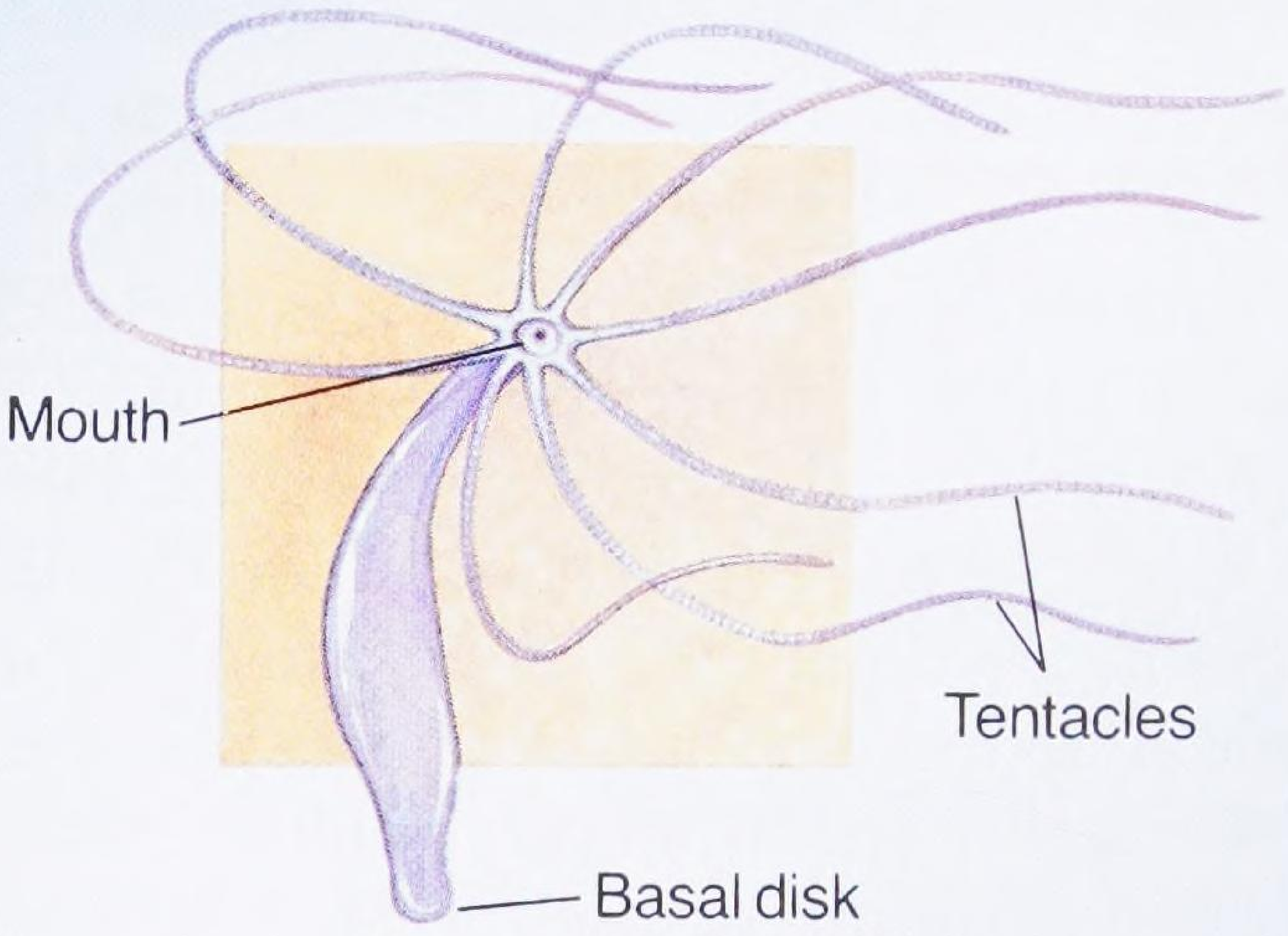
Problem: *How does a hydra react?*

Materials

- dropper
- hydra culture
- small dish
- toothpick
- Daphnia or brine shrimp
- stereoscopic microscope

Procedure

1. Use a dropper to place a hydra into a dish along with some of the water in which it is living.
2. Place the dish on the stage of the stereoscopic microscope. Bring the hydra into focus. Record the color of the hydra.
3. Identify and count the number of tentacles. Locate the mouth.
4. *Observe* the basal disk by which the hydra attaches itself to a surface.
5. *Predict* what will happen if the hydra is touched with a toothpick. Carefully touch the tentacles. Then gently touch the basal disk. Describe the reactions in the data table.
6. Drop a Daphnia or a small amount of brine shrimp into the dish. Observe how the hydra takes in food. Record your observations.
7. Return the hydra to the culture.



Data and Observations

Features	Observations
Color	
Number of tentacles	
Reaction to touch	
Tentacles	
Basal disk	
Reaction to food	

Analyze

1. How many tentacles does the hydra have?
2. Where is the mouth located in relation to the tentacles?
3. Did the hydra react to touch as you predicted?
4. How did the hydra react to food?

Conclude and Apply

5. When the hydra was touched, did anything happen to other areas of the animal?
6. What advantage do tentacles give hydra?

The Simple Worms

13-4

Objectives

- Compare the body plans of flatworms and roundworms.
- Distinguish between free-living and parasitic organisms.
- Identify disease-causing flatworms and roundworms.

New Science Words

free-living
anus
cyst

Flatworms

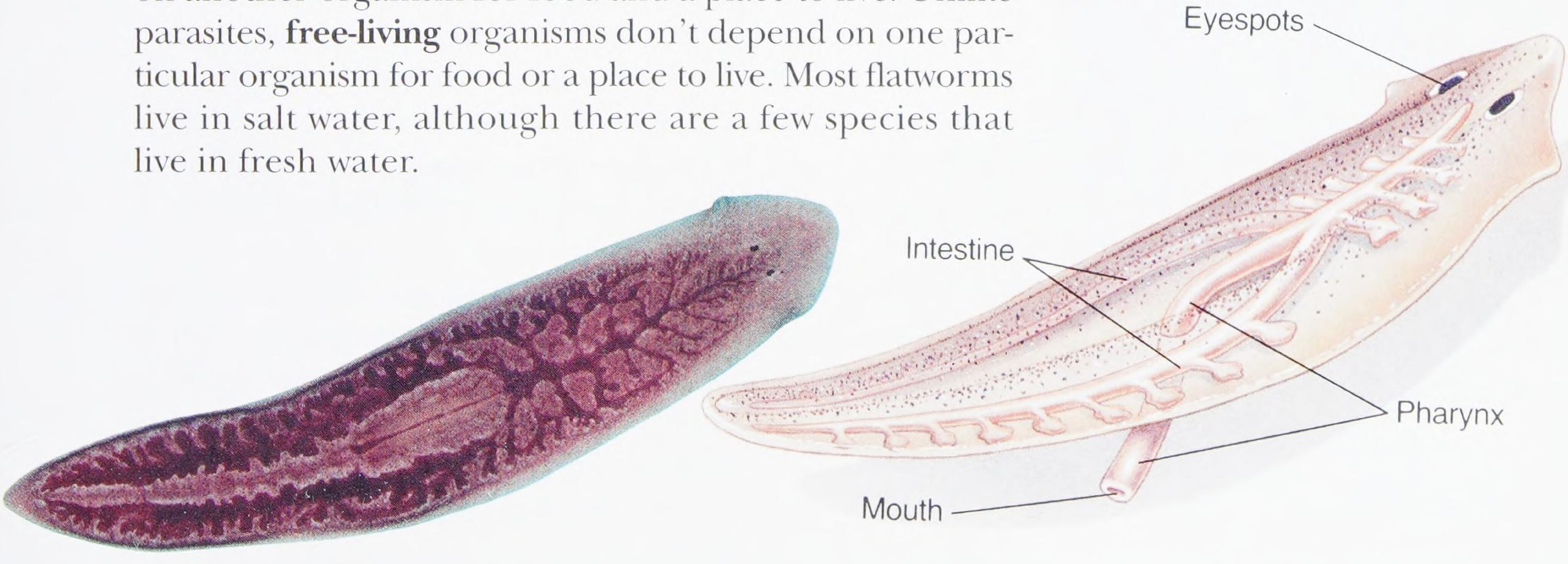
The animal you most likely think of when you hear the word *worm* is the earthworm—the worm that crawls across pavement after a rain, or the worm used to bait a fishing hook. You probably wouldn't think immediately of tapeworms or any of the other many types of worms in the world. Just what is a worm? Worms are invertebrates with soft bodies and bilateral symmetry. They have three layers of tissues, organs, and organ systems. Worms live in many different environments. Some are very beautiful; others are not so attractive. There are flatworms, roundworms, and worms with segments. In this chapter, you will learn about flatworms and roundworms.

As their name implies, flatworms have flattened bodies. They are members of the phylum Platyhelminthes (plat ih hel MIHN theez). Members of this phylum include planarians and tapeworms. Some flatworms are free-living but most are parasites. Remember a parasite depends on another organism for food and a place to live. Unlike parasites, **free-living** organisms don't depend on one particular organism for food or a place to live. Most flatworms live in salt water, although there are a few species that live in fresh water.

MINI-Lab

How do planarians move?
Use a dropper to transfer a planarian to a watch glass. Add enough water so the worm can move freely. Place the glass under a stereomicroscope and *observe*. **In your Journal,** describe how the organism moves in the dish. Draw the organism.

Figure 13-12. Planarians have a simple body structure.



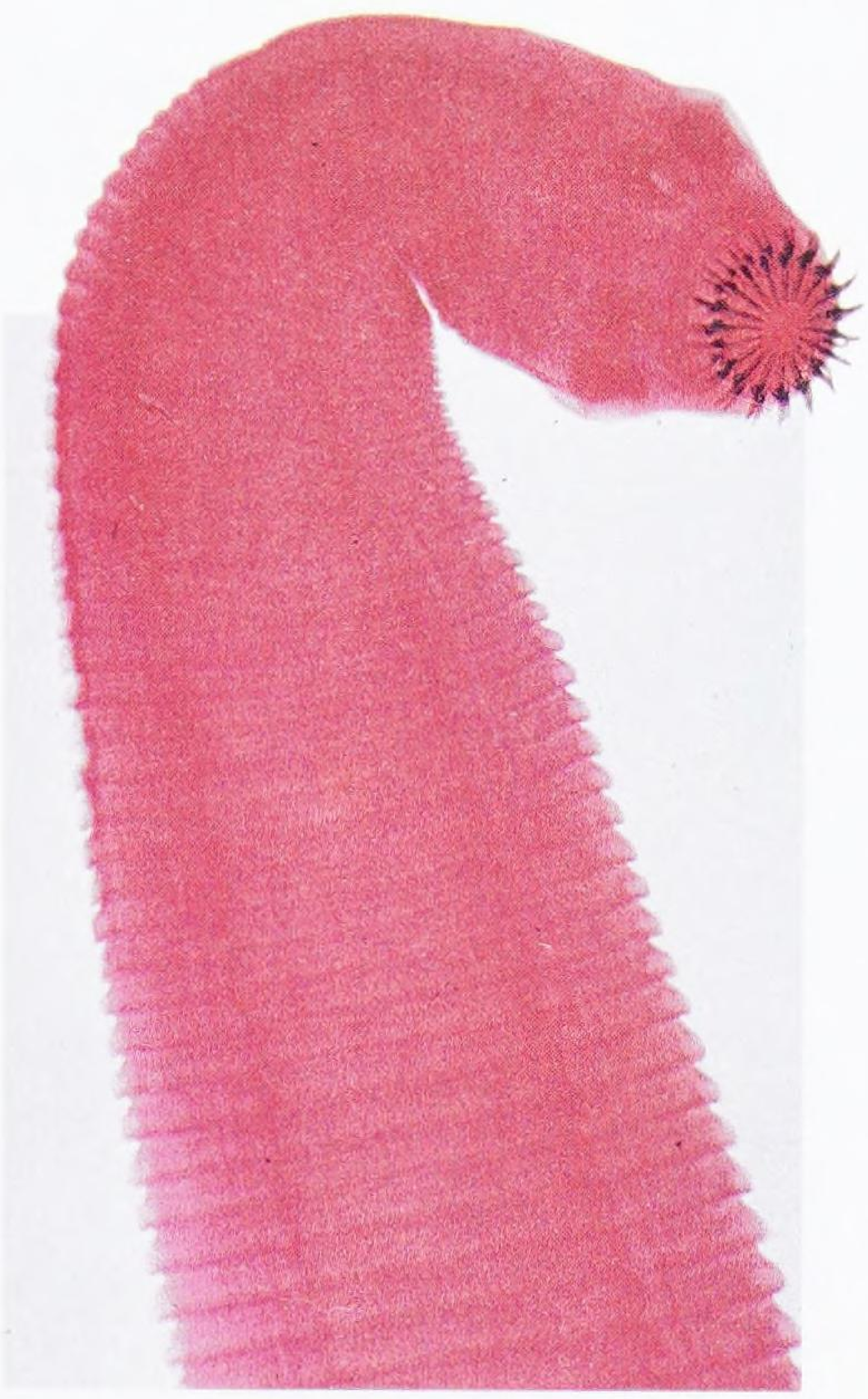
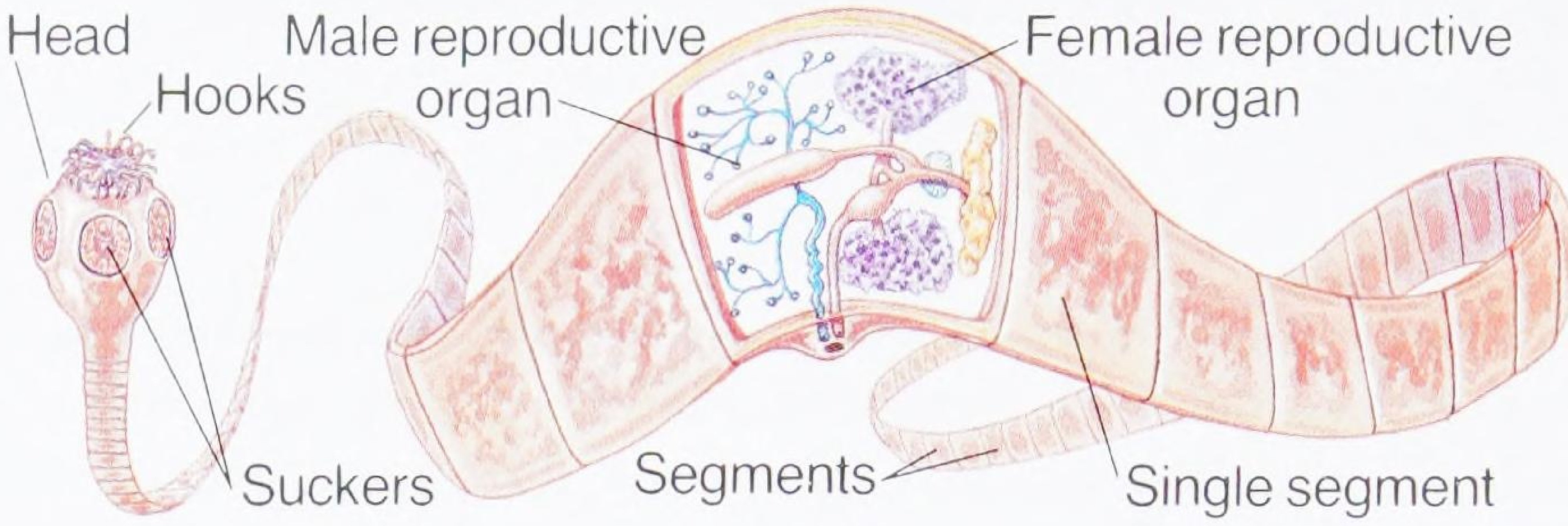


Figure 13-13. Tapeworms attach to an organism's intestine using hooks and suckers. A section of a tapeworm is made mostly of separate segments that contain male and female reproductive structures. Like most parasites, tapeworms produce huge numbers of eggs.



A planarian, like the one in Figure 13-12, is an example of a free-living class of flatworms. It has a triangle-shaped head with two eyespots. There is one body opening, a mouth, on the ventral side of the body. A muscular tube called the pharynx connects the mouth and the digestive tract. A planarian feeds on small organisms and dead bodies of larger organisms. Most planarians live in fresh water, under rocks, or on plant material. Some live in moist places on land. The body of a planarian is usually about one centimeter long and is covered with cilia. The cilia move the worm along in a slimy mucus track secreted by the underside of the planarian.

Planarians reproduce asexually or sexually. They reproduce asexually simply by dividing in two. Planarians also have the ability to regenerate. A planarian can be cut in two, and each piece will grow into a new worm. Planarians reproduce sexually by egg and sperm. Most are hermaphrodites, and they exchange sperm with one another. They lay fertilized eggs that hatch in a few weeks.

Tapeworms are parasitic members of the phylum Platyhelminthes. These worms use hooks and suckers to attach themselves to the intestine of a host organism. Dogs, cats, humans, and other animals are hosts for tapeworms. A tapeworm doesn't have a mouth or a digestive system. Food that has already been digested by the host is absorbed from the intestine of the host by the worm. A tapeworm grows by producing new body segments behind the head. Its ribbonlike body may grow to be 12 meters long.

Each body segment of the tapeworm has both male and female reproductive organs. The segments produce eggs and sperm, and the eggs are fertilized in the segment. Once a segment is filled with fertilized eggs, it breaks off and passes out of the host's body. If a fertilized egg is eaten by another host, the egg hatches and develops into a new worm.

MINI-Lab

How do planarians respond to light?

Use a dropper to transfer a planarian to a watch glass. Add enough water so the worm can move freely. Place a piece of foil to cover half of the watch glass; place under a stereomicroscope and observe. *Predict* the direction the worm will move in—toward or away from the light.

Roundworms

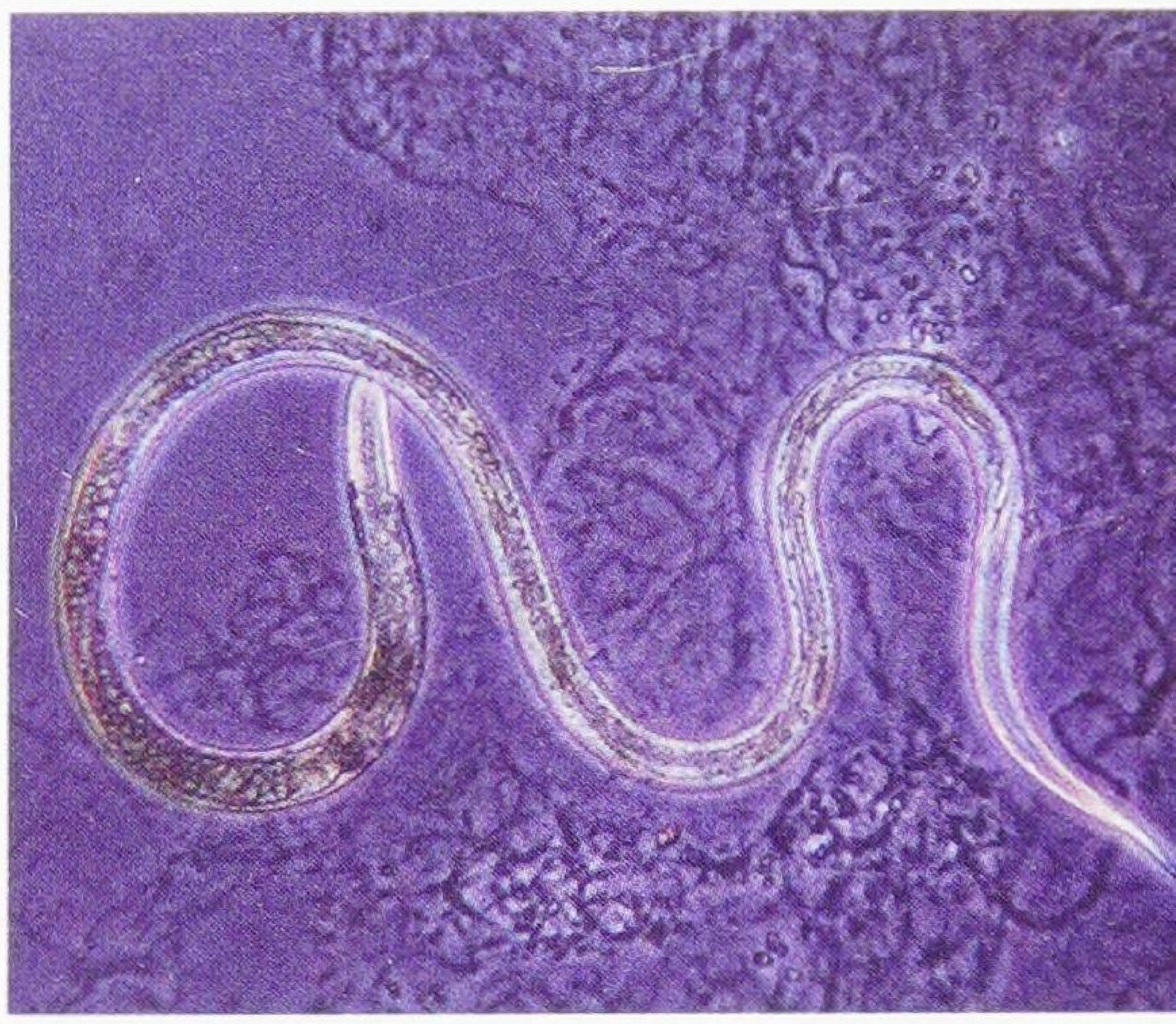


Figure 13-14. This free-living species of roundworm lives among cyanobacteria.

If you own a dog, you've probably had to get medicine from your vet to protect your dog from heartworm. Heartworm is a disease in dogs caused by roundworms. Roundworms make up the largest phylum of worms, the phylum Nematoda. It is estimated that there are more than a half million species of roundworms in the phylum Nematoda. Nematodes are found in soil, in animals, and in fresh water and salt water. Many are parasitic, but most are free-living.

Roundworms are slender and tapered at both ends. The body is a tube within a tube, with fluid in between. Unlike the organisms you have studied so far, Nematodes have two body openings, a mouth and an anus. The **anus** is an opening at the end of the digestive tract through which wastes leave the body.

Some roundworms are parasites of humans. The most common roundworm parasites of humans are *Ascaris*, hookworm, and *Trichinella*. Humans get hookworms by

PROBLEM SOLVING

Barbara's New Puppy

Barbara received a new puppy for her birthday. Barbara and her parents took the puppy to a veterinarian for a checkup. After the examination, the veterinarian gave Barbara some medication to give her puppy daily to prevent heartworm disease. He explained how she should increase the dosage as the puppy gains weight.

The vet told her that it was important to give the puppy the medication every day. Heartworms are spread from dog to dog by mosquitoes. When a mosquito bites a dog infected with heartworms, it can pick up and carry them to a dog not infected. Dogs can get heartworms at anytime during their life if they don't receive medication.

How can heartworm disease be controlled?

Think Critically: Why should the dosage of heartworm medication be increased as the puppy gains weight?

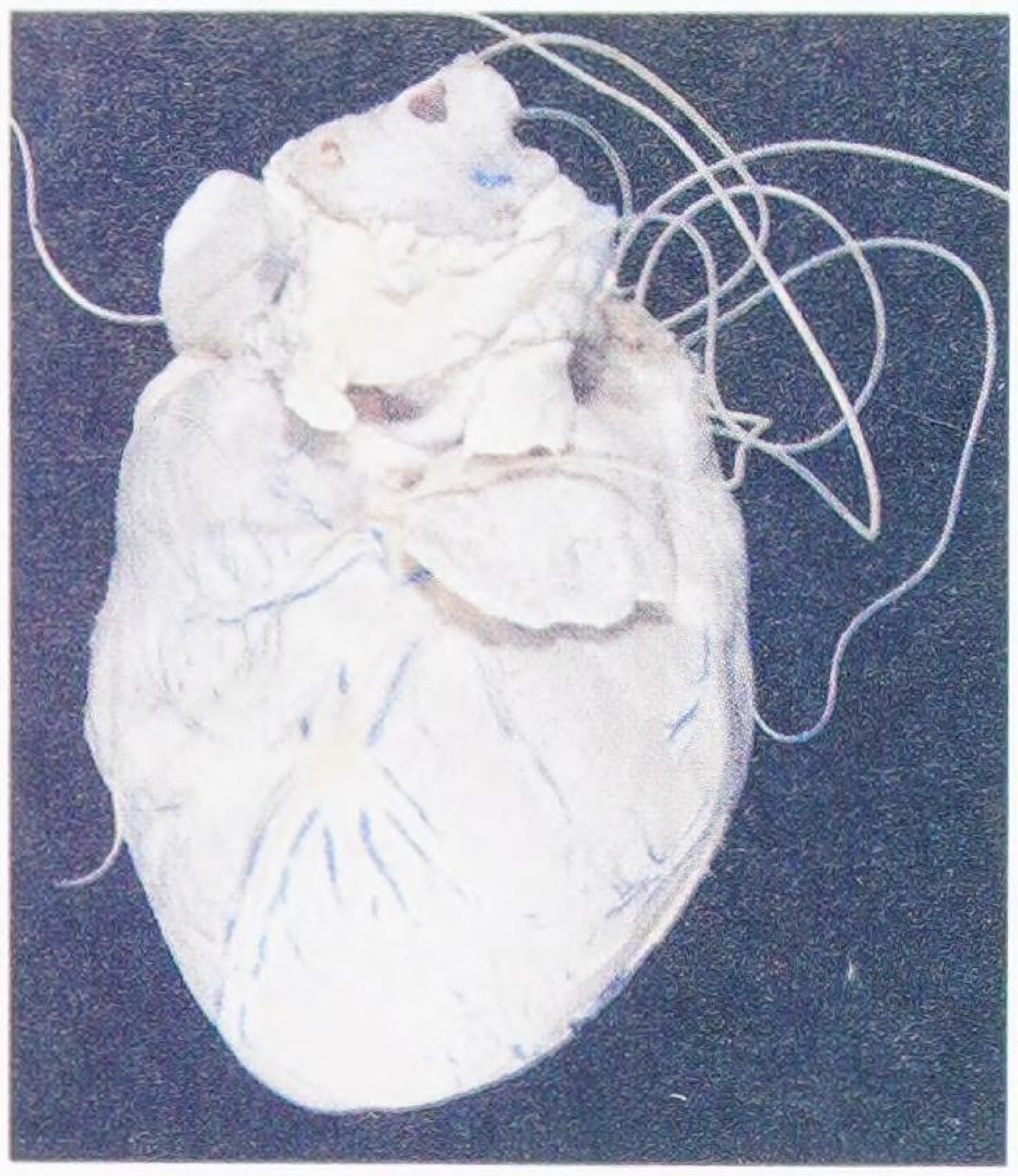


Figure 13-15. This heart of a dog is infected with heartworms.

walking barefoot over dirt or through fields. Hookworm eggs hatch in warm, moist soil. Wearing shoes is the best protection against hookworms.

Ascaris is found in the intestines of pigs, horses, and humans. Eggs enter the host's body in contaminated food or water. They travel to the intestines where they mature and mate. Masses of worms can block the intestines and cause death if left untreated.

Trichinella worms cause the disease trichinosis (trihk uh NOH sus). Humans become infected when they eat undercooked pork that has *Trichinella* cysts. A **cyst** is a young worm with a protective covering. Trichinosis can be prevented by thoroughly cooking pork.

The heartworms you treat your dog for enter the blood of a dog through a mosquito bite. They move to the heart, where they grow and reproduce. They can block the valves of the heart that lead to and from the lungs if the infection is left untreated. Medicine can be given to dogs to prevent heartworm disease.

The flatworms and roundworms are more complex than sponges and cnidarians. They have bilateral symmetry, three well-developed tissue layers, and organ systems. The roundworms have digestive systems with a mouth and an anus. Like sponges and cnidarians, these invertebrates probably evolved in the sea. They still live in moist environments.

In Your JOURNAL

In your Journal, write a public service announcement for your local television station informing the community about heartworm disease in dogs. A veterinarian can probably provide much useful information.

SECTION REVIEW

1. Compare body plans of flatworms and roundworms.
2. Give an example of a free-living flatworm and a parasitic flatworm.
3. What are three roundworms that cause diseases in humans? How can humans prevent infection?
4. **Apply:** Which organism is more complex, a cnidarian or a flatworm? Explain.
5. **Connect to Chemistry:** Suggest a reason why tapeworms are not digested by their hosts.

Skill Builder

Outlining

Make an outline of the concepts found in Section 13-4. If you need help, refer to Outlining in the **Skill Handbook** on page 681.

CHAPTER REVIEW

SUMMARY

13-1: What Is an Animal?

1. Animals are many-celled eukaryotic organisms that must find and digest their food.

2. Animals that have body parts arranged the same way on both sides of the body have bilateral symmetry. Animals with body parts in a circle around a central point are radially symmetrical.

3. Invertebrates are animals that don't have backbones. Animals with backbones are vertebrates.

13-2: Science and Society: Experiments Using Animals

1. Many lifesaving drugs and vaccines have been developed using animals for testing.

2. Many people feel animals have rights and should be treated humanely and with respect.

13-3: The Simplest Invertebrates

1. Sponges are considered the simplest animals in the animal kingdom. They are sessile and obtain food and oxygen by filtering water through pores. Sponges reproduce by egg and sperm and by budding or regeneration.

2. Cnidarians are hollow-bodied animals with radial symmetry. Most have tentacles with stinging cells to obtain food. Digestion takes place in a central cavity. Jellyfish, hydras, and corals are cnidarians.

13-4: The Simple Worms

1. Flatworms belong to the phylum Platyhelminthes. They have bilateral symmetry. There are both free-living and parasite forms. Planarians have one body opening. Tapeworms are parasitic forms of flatworms that have hooks and suckers to attach to a host. Roundworms belong to the phylum Nematoda. They have a tube within a tube body plan and bilateral symmetry. Roundworms have two body openings, a mouth and anus.

2. Free-living organisms don't depend on one particular organism for food or a place to live. Parasites depend on other organisms for food and a place to live.

3. Some parasitic roundworms that infect humans are hookworms, *Ascaris,* and *Trichinella.* Heartworms are roundworms that infect dogs.

KEY SCIENCE WORDS

a. **anus**
b. **bilateral symmetry**
c. **cnidarians**
d. **collar cells**
e. **cyst**
f. **filter feeders**
g. **free-living**
h. **hermaphrodite**
i. **invertebrates**
j. **larva**
k. **medusa**
l. **polyp**
m. **Porifera**
n. **radial symmetry**
o. **regeneration**
p. **sessile**
q. **tentacles**
r. **vertebrates**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. body parts the same on each side
2. a young worm enclosed in a covering
3. a young organism different from the adult
4. opening for digestive wastes
5. attached, nonmoving animal
6. organisms with no backbones
7. animals that have backbones
8. cnidarian shaped like a tube or vase
9. an organism that makes both egg and sperm
10. used by cnidarians to capture food

CHAPTER REVIEW

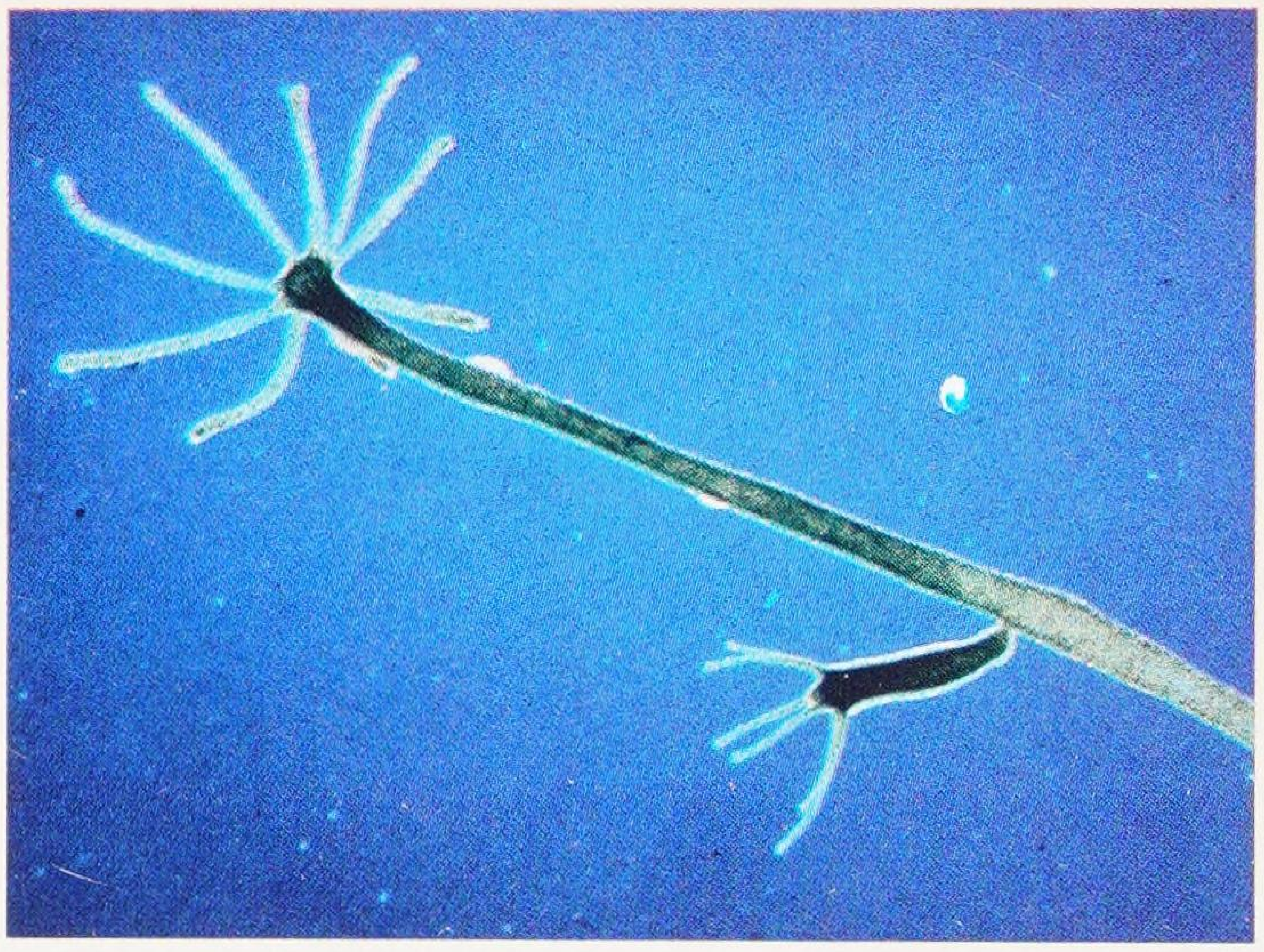
CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. Animal characteristics include all of the following except ______.
   a. movement c. eukaryotic cells
   b. digestion d. prokaryotic cells
2. All of these belong to the same group except ______.
   a. fish c. jellyfish
   b. clam d. sponge
3. ______ is the opposite of dorsal.
   a. Anterior c. Radial
   b. Ventral d. Bilateral
4. Scientists classify sponges based on ______.
   a. kind of spicules
   b. reproduction
   c. method of obtaining food
   d. symmetry
5. Sponges are members of Phylum ______.
   a. Cnidaria c. Porifera
   b. Nematoda d. Platyhelminthes
6. Sponges reproduce by ______.
   a. regeneration c. budding
   b. polyps d. egg and sperm
7. The body plans of cnidarians are polyp and ______.
   a. larva c. ventral
   b. medusa d. buds
8. All are examples of cnidarians except ______.
   a. coral c. planarian
   b. hydra d. jellyfish
9. An example of a parasite is a ______.
   a. sponge c. tapeworm
   b. planarian d. jellyfish
10. Separate sexes are found in ______.
   a. *Ascaris* c. sponges
   b. planarian d. cnidarians

USING LAB SKILLS

11. The Activity on page 305 asked you to determine the symmetry of some animals. Use this activity to determine the symmetry of the following animals: coral, squid, sand dollar, dog, and planarian.
12. Use your prediction about planaria response in the MINI-Lab on page 316, to **hypothesize** how the planarian would react to light. Then **design an experiment** to test your hypothesis.



THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Using an example, explain the difference between bilateral and radial symmetry.
14. Explain the difference between budding and regeneration.
15. Why do scientists feel that reforms and regulations in animal research may threaten the future of science?
16. Explain how the structure of a tapeworm and its life-style are related.

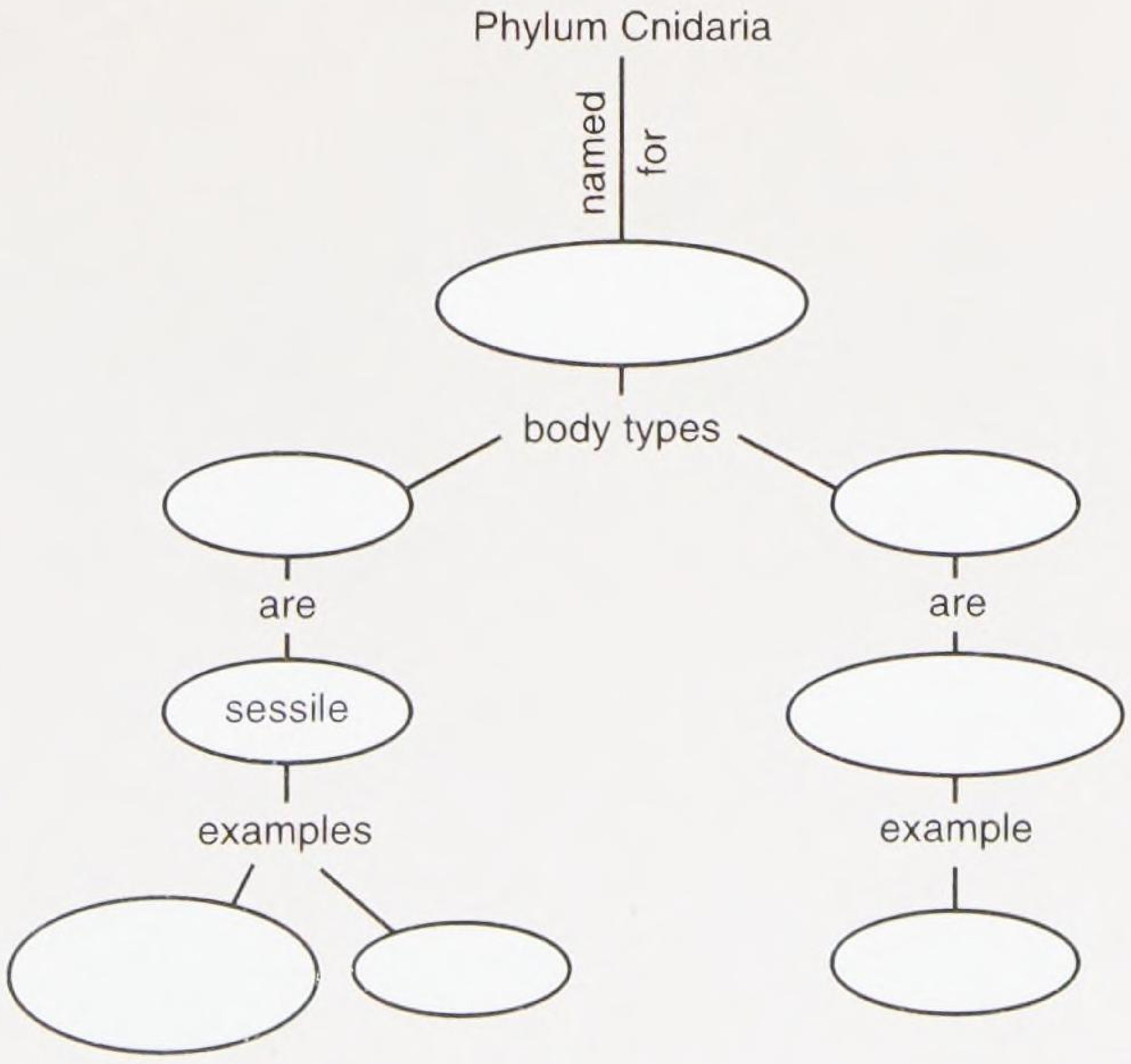
APPLY

17. Compare the body organization of a sponge to that of a simple worm.
18. What is the advantage of having more than one means of reproduction in simple animals?
19. List the types of food sponges, hydras, and planarians eat. Explain why the size of the food particles is different in each organism.
20. Compare and contrast the medusa and polyp body forms of cnidarians.
21. What are some reasons why scientists think the medusa stage was the first stage of the cnidarians?

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Sequencing:** Sequence the order of heartworm infection in a dog.
2. **Using Variables, Constants, and Controls:** Design an experiment to test the sense of touch in a planarian.
3. **Concept Mapping:** Complete the concept map of classification in the animal kingdom.



4. **Hypothesizing:** Make a hypothesis about cooking pork at high temperatures to prevent worms from developing, if present in the uncooked meat.
5. **Observing and Inferring:** Observe the animals pictured in Activity 13-1. Use Figure 13-2 on page 303 to determine to which phylum each animal belongs.

PROJECTS

1. Make a map of the areas of the world where parasitic worms are problems for humans. What conditions cause the high rate of infection in people in these areas?
2. With your teacher, look in a stream on and under rocks for flatworms and roundworms. Observe them under the microscope.

CHAPTER

14 Complex Invertebrates

If you've ever walked along a beach, you've probably seen lots of seashells. Seashells come in many different colors, shapes, and sizes. Each shell is made of many rings or bands. Can you learn anything about the shell and the organism that made it by looking at the bands?

FIND OUT!

Do this simple activity to find out how many bands are on a clam shell and what they mean.

Use a hand lens to observe a clam shell. Count the number of rings or bands on the shell. Count the large top point called the crown as one ring. Are all of the bands the same width? *Predict* what the width of the bands tells you about a year in the life of the clam. *Compare* your results with those of your classmates. Do all of the clams have the same number of bands? *Infer* what the bands represent. Why do you think some are wider than others?

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 14-1 Mollusks
- Features of Mollusks
- Classes of Mollusks
- Importance of Mollusks

Section 14-2 Segmented Worms
- Features of Segmented Worms
- Types of Segmented Worms
- Evolution of Segmented Worms and Mollusks

Section 14-3 Arthropods
- Features of Arthropods
- Classes of Arthropods

Section 14-4 Science and Society Pesticides
- Insect Pests?

Section 14-5 Echinoderms
- Features of Echinoderms
- Sea Stars

Previewing Science Skills

- In the **Skill Builders,** you will compare and contrast, interpret scientific illustrations, make a concept map, and observe and infer.
- In the **Activities,** you will observe, experiment, and collect and record data.
- In the **MINI-Labs,** you will experiment, observe, and record data.

What's next?

In this chapter you will study mollusks, segmented worms, arthropods, and echinoderms. You will learn about the lives of these organisms and about how these organisms are important to you and the environment.

14-1 Mollusks

New Science Words

mollusks
mantle
gills
open circulatory system
radula
closed circulatory system

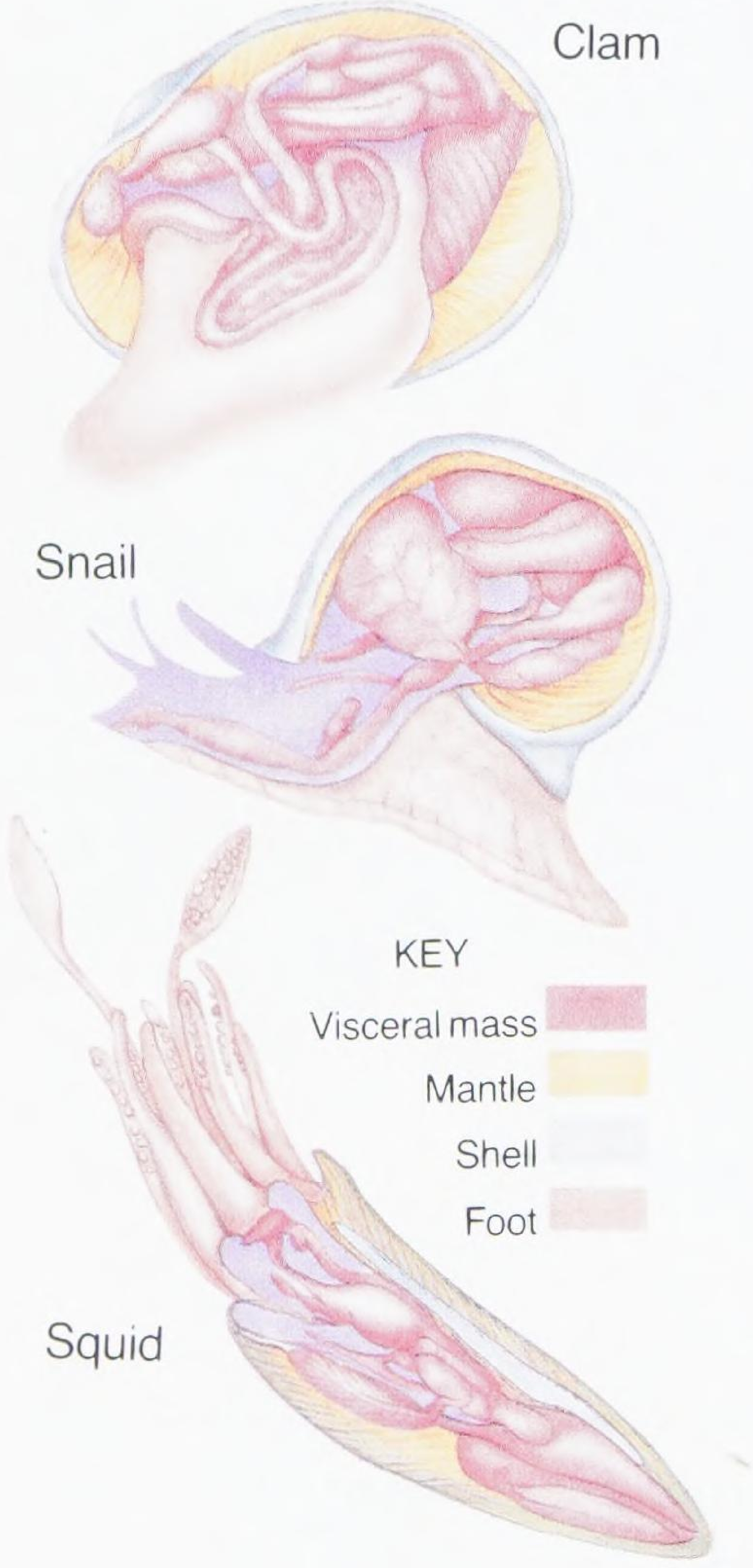
Objectives

- Identify the features of mollusks.
- Name three classes of mollusks and identify a member of each.

Features of Mollusks

If you've collected shells on the beach, watched a snail crawl, or eaten oysters or squid, you are familiar with mollusks. The word *mollusk* comes from the Latin word meaning "soft," and describes the bodies of the organisms in the phylum Mollusca (mah LUS kuh). **Mollusks** are soft-bodied invertebrates that usually have shells. They are found on land, in fresh water, and in salt water. Like the simple worms, mollusks have bilateral symmetry. Unlike the simple worms, sponges, and cnidarians, mollusks have a fluid-filled body cavity that provides space for the body organs.

Figure 14-1. All mollusks have the same basic body plan: a shell, foot, mantle, and visceral mass.



Mollusks come in many different sizes, shapes, and colors. They vary in size from the tiny aquarium snail to the giant squid that can reach a length of 18 m. Different as they are, all mollusks have the same basic body plan.

All mollusks have a soft body usually covered by a hard shell. Covering the soft body is the mantle. The **mantle** is a thin layer of tissue that secretes the shell or protects the body if the mollusk does not have a shell. Between the soft body and the mantle is a space called the mantle cavity. In it are the **gills,** organs that exchange oxygen and carbon dioxide with the water. The body organs of mollusks are located together in an area called the visceral mass. The mantle covers the visceral mass. Finally, all mollusks have a muscular foot used for movement.

The circulatory system of most mollusks is an **open circulatory system.** In this type of system blood isn't completely contained in vessels the way your blood is. Blood bathes a mollusk's organs directly in some areas of their bodies.

The classification of mollusks is based on whether or not a shell is present; if a shell is present, the kind of shell it is; and the kind of foot. In this section, you will learn about three classes of mollusks.

Classes of Mollusks

Univalves

The largest class of mollusks includes snails, slugs, abalones, whelks, sea slugs, and conches. Look at the organism in the top photograph of Figure 14-2. Can you see why these organisms are called one-shelled mollusks, or univalves? Except for slugs, each member of this class has a single spiral shell. Many have a pair of tentacles with eyes at the tips. Food is obtained with a radula. The **radula** is a tongue-like organ with rows of teeth that work like a file. It is an adaptation used for scraping and tearing algae and other food materials.

Univalves are adapted for different ways of life. Slugs and many snails are adapted to life on land. They move by muscular contractions of the foot. Glands in the foot secrete a layer of mucus for the foot to slide along in. Slugs live where it is moist. Slugs do not have shells, but they are protected by a layer of mucus.

Bivalves

Bivalves are two-shelled mollusks that have a two-part shell joined by a hinge. *Bivalve* means "two-shelled." Clams, oysters, and scallops are bivalve mollusks. These animals pull their shells closed with powerful muscles. To open their shells, they relax these muscles. The shell is made up of several layers made by the mantle. The smoothest layer is on the inside and protects the soft body.

Bivalves are very well adapted to living in water. For protection, clams burrow deep into the sand with their muscular foot. Mussels and oysters cement themselves to a solid surface or attach themselves with a strong thread. This keeps strong waves from washing them away. Scallops escape predators by rapidly opening and closing their shells. As the water pours out, its force moves them rapidly in the opposite direction.

Cephalopods

The class of mollusks with the most specialized and complex members are the cephalopods. The word *cephalopod* means "head-footed," and describes the body structure of these invertebrates. Squid, octopus, and the chambered nautilus belong to this class. Cephalopods have a large, well-developed head. Their "foot" is divided into many tentacles with strong suckers for capturing

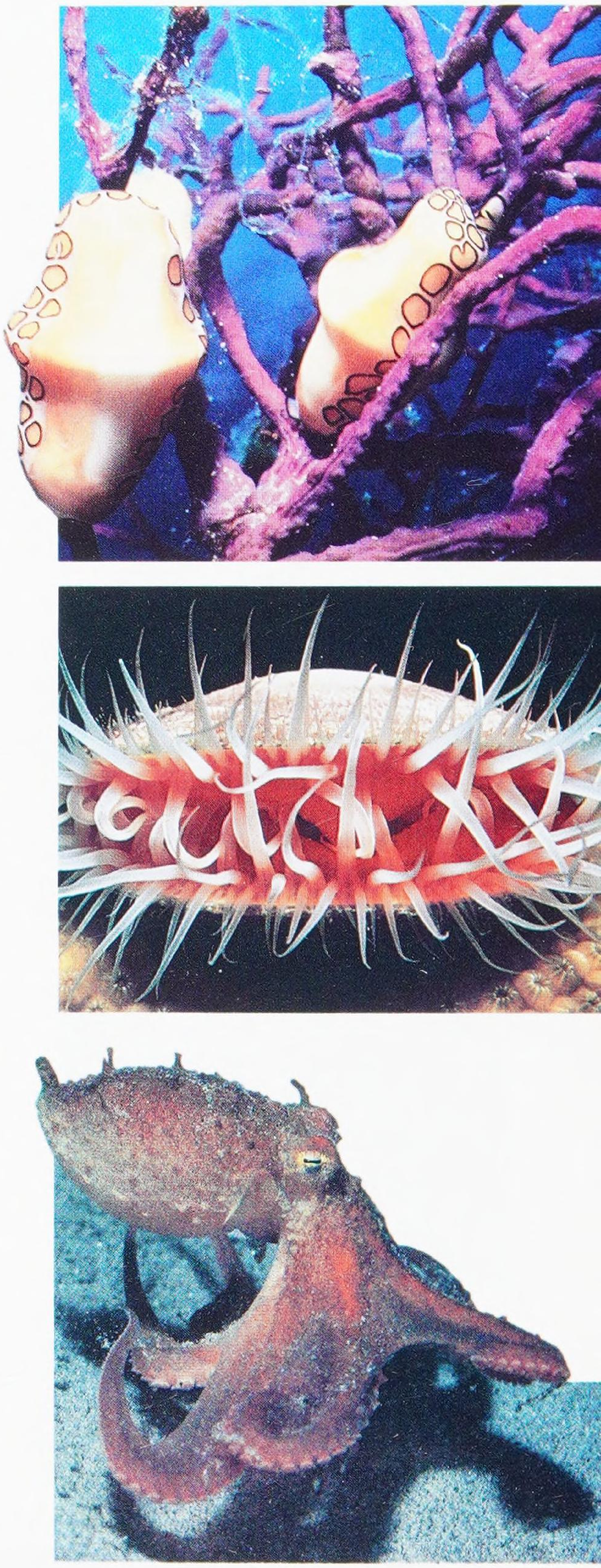


Figure 14-2. The organism in the top photo is a representative of the univalves. The scallop in the middle photo is a bivalve and the octopus in the bottom photo is a cephalopod.

prey. Squid and octopuses have a well-developed nervous system and large eyes similar to human eyes. Unlike the other mollusks, in head-footed mollusks, blood containing food and oxygen is contained and transported in a series of vessels, in a **closed circulatory system.**

All cephalopods live in oceans and have bodies adapted for swimming. They move quickly by jet propulsion. When the space under the mantle is filled with water, they contract their mantle muscles and force water from an opening near the head. The jet of water sends them backward. A squid can swim at more than 60 m per second this way. Although octopuses can swim by jet propulsion like squid can, they usually use their tentacles to creep more slowly over the ocean floor.

Connect to... Physics

According to Newton's Third Law of Motion, when one object exerts a force on a second object, the second object exerts an equal but opposite force on the first. *Infer* how this law is represented in the movement of a squid.

Importance of Mollusks

Mollusks provide food for fish, sea stars, and birds. Their empty shells provide homes for invertebrates such as hermit crabs. Clams, oysters, snails, and scallops are used for food. Pearls are produced by many species of mollusks, but most are made by pearl oysters. Scientists are studying the nervous systems of squid and octopus to understand how learning takes place and how memory works. Mollusks can also cause problems. Snails and slugs feed on plants and damage crops. Certain species of snails are hosts of parasites that infect humans.

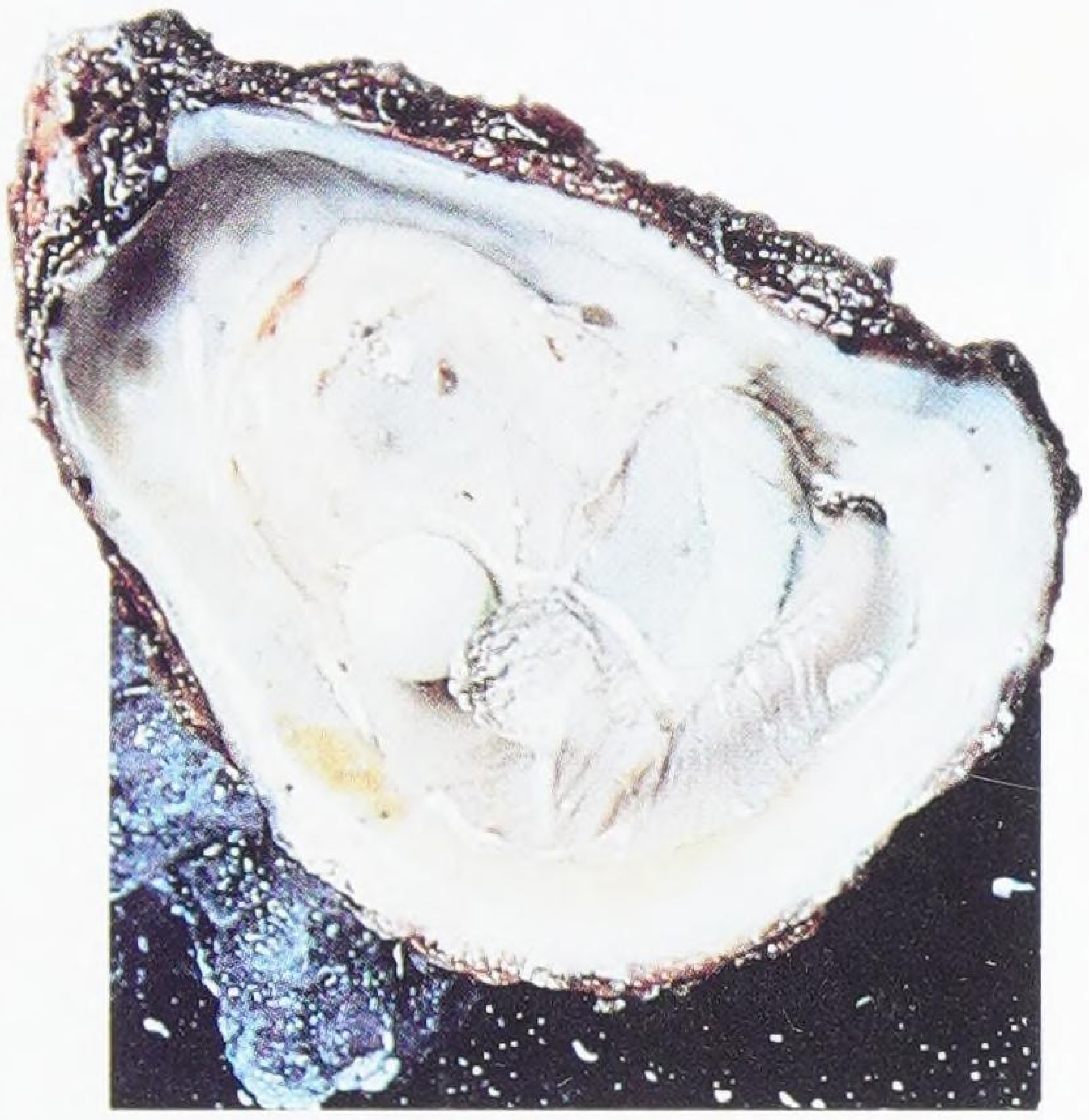


Figure 14-3. Pearls are formed in many bivalve mollusks. Smooth mother of pearl is secreted by the mantle in layers around a grain of sand or other particle trapped between the mantle and the shell.

SECTION REVIEW

1. What features are used to classify mollusks?
2. Name the three classes of mollusks and identify a member from each class.
3. **Apply:** What adaptation makes a snail useful to have in an aquarium?
4. **Connect to Physics:** Find out what a scallop does to escape a predator.

Skill Builder

Comparing and Contrasting

Make a table that compares and contrasts the features of one-shelled mollusks, two-shelled mollusks, and head-footed mollusks. If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.

Segmented Worms

14-2

Objectives

- Describe the traits of segmented worms.
- Describe the structures and digestive process of an earthworm.
- Identify the evolutionary relationship between segmented worms and mollusks.

New Science Words

setae
crop
gizzard

Features of Segmented Worms

The worms you see crawling across sidewalks and driveways after a hard rain and the night crawlers you dig up for fishing belong to the phylum Annelida (uh NEL ud uh). The phylum Annelida is made up of segmented worms. Their tube-shaped bodies are divided into many little sections, or segments. The word *annelid* means "little rings" and describes the bodies of these worms. Segmented worms are found in fresh water, salt water, and moist soil. Earthworms, leeches, and beautiful fan worms belong to this phylum.

Besides segments, members of this phylum have several other characteristics in common. Like mollusks, all segmented worms have a body cavity that holds their organs. On the outside of each segment, are bristle-like structures called **setae** (SEE tee) that help the worms move. Have you ever watched a bird try or tried yourself to pull an earthworm out of the ground? It's not that easy, is it? Segmented worms use their setae to hold on to the soil. Let's look more closely at two classes of segmented worms—earthworms and leeches.

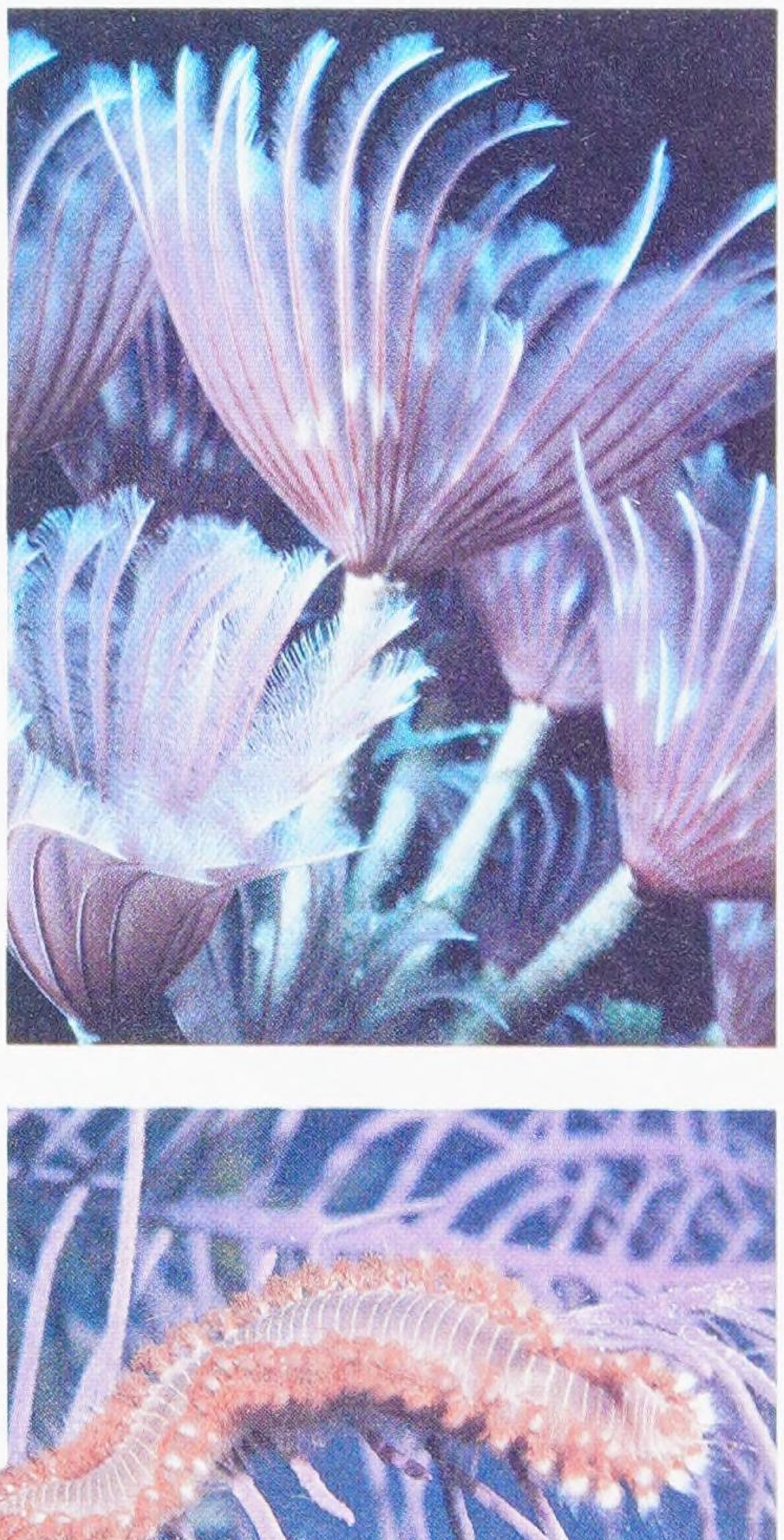


Figure 14-4. Featherduster worms (top) and fireworms (bottom) are two types of segmented worms that live in the ocean.

Types of Segmented Worms

Earthworms

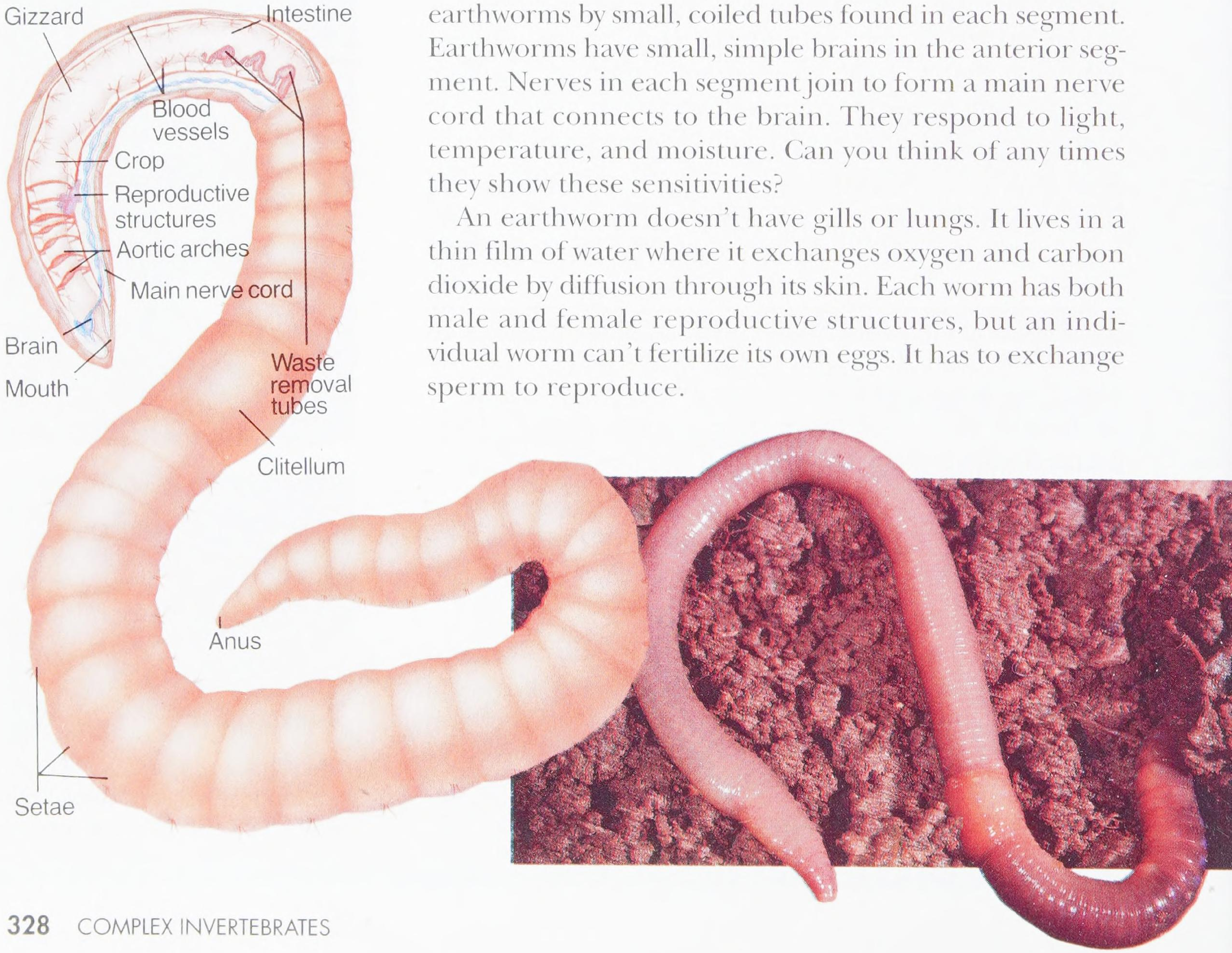
The tube-like body of an earthworm is divided into more than 100 segments. The segments aren't only on the outside; the body cavity is divided also. Each segment is identical except for those near the front and hind ends. Each body segment, except for the first and last, has two pairs of setae. Earthworms move by using their setae and two sets of muscles in the body wall.

To get food, earthworms eat soil! While they burrow through the soil they are actually eating it. Earthworms get the energy they need to live from the bits of leaves and other plant and animal materials found in the soil. The digestive system of an earthworm is made up of a crop, gizzard, and intestine. The soil eaten by an earthworm moves to the **crop,** which is a sac used for storage. Behind the crop is a muscular structure, the **gizzard,** that grinds the soil. In the intestine, which follows, food is broken down and absorbed by the blood. Undigested soil and waste materials leave the worm through the anus.

Look at the body structure of an earthworm in Figure 14-5. Earthworms have two blood vessels along the sides of the body that meet in the anterior, or front, end. The vessels meet here and form five pairs of structures, called aortic arches, that pump blood through the body. Smaller vessels go into each body segment. Because an earthworm's blood is all contained in tubes and vessels, it has a closed circulatory system. Wastes are removed from earthworms by small, coiled tubes found in each segment. Earthworms have small, simple brains in the anterior segment. Nerves in each segment join to form a main nerve cord that connects to the brain. They respond to light, temperature, and moisture. Can you think of any times they show these sensitivities?

An earthworm doesn't have gills or lungs. It lives in a thin film of water where it exchanges oxygen and carbon dioxide by diffusion through its skin. Each worm has both male and female reproductive structures, but an individual worm can't fertilize its own eggs. It has to exchange sperm to reproduce.

Figure 14-5. Segmented worms have circulatory, respiratory, excretory, digestive, muscular and reproductive systems.



TECHNOLOGY

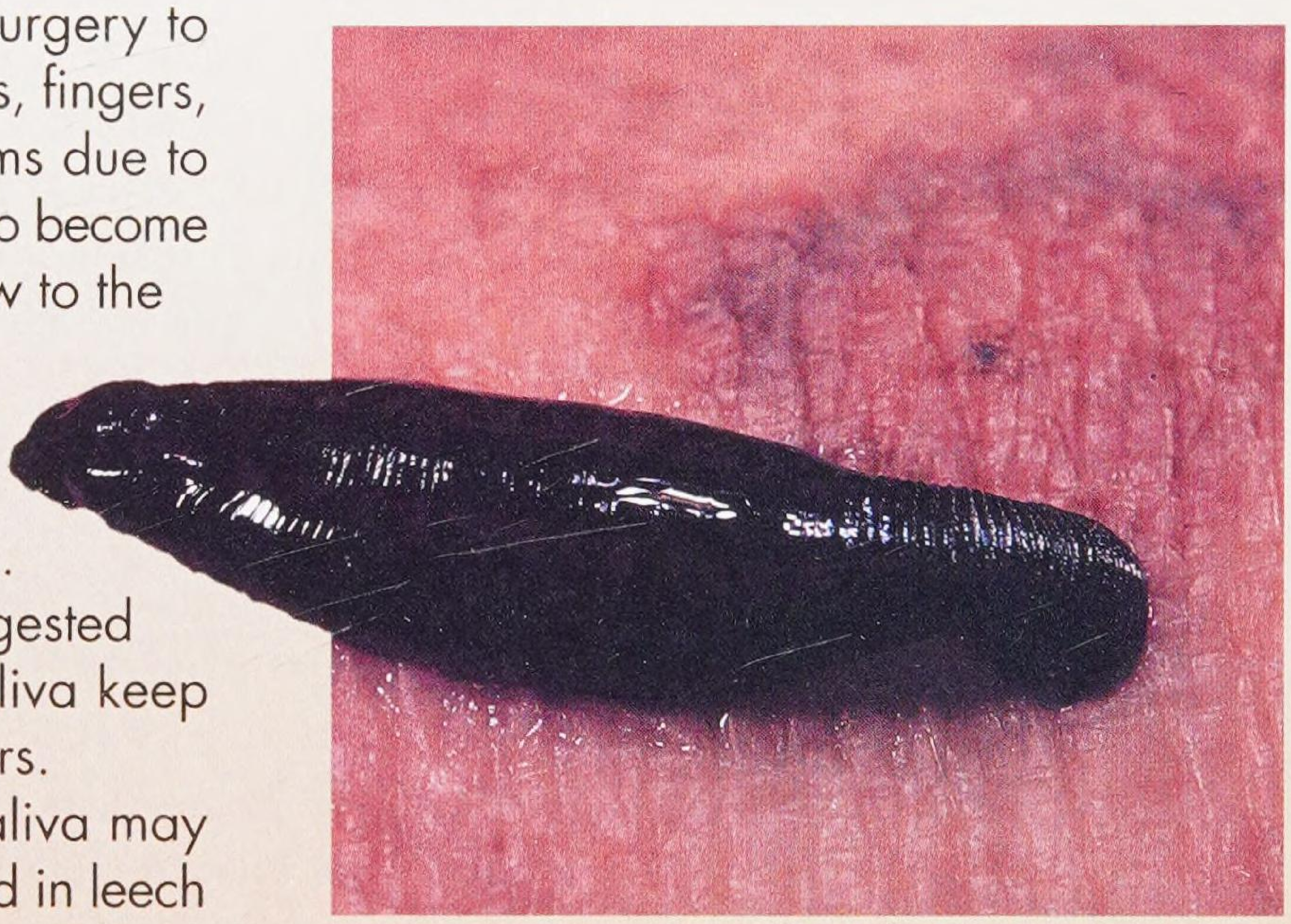
Leeches to the Rescue

No one likes to meet a leech by accident, but some hospital pharmacies now stock leeches, in various sizes, for use in delicate microsurgery. In fact, a major leech farm ships 25 000 leeches each year to two dozen countries.

When doctors perform microsurgery to reattach small body parts like ears, fingers, and toes, they may have problems due to the tiny veins involved. These tend to become blocked and cut off the blood flow to the reattached tissue. Without a good blood flow, the tissue dies. To prevent this, surgeons attach leeches to the microsurgery site. The leeches suck some of the congested blood, and chemicals in their saliva keep the blood flowing for several hours.

Other chemicals in leeches' saliva may be beneficial. Scientists have found in leech saliva an anticlotting substance, an anesthetic, and a chemical that increases the size of veins.

Think Critically: How could these chemicals be useful for patients with circulatory problems?



Leeches

You or someone you know may have had to remove a leech from your body while swimming in a pond, lake, or river. Leeches belong to another class of segmented worms and are adapted to a life-style very different from earthworms. Their bodies are not as round or long as earthworms', and they don't have setae. Leeches feed on the blood of ducks, fish, and even humans. Two suckers, one at each end of the body, are used to attach to an animal. After the leech has attached itself, it cuts open a wound and sucks two to ten times its weight in blood. If you have had a leech attached to you, you know that when you pulled it off, the wound didn't stop bleeding for quite a long time. This is because the leech secretes a substance to keep your blood from clotting so it can feed more easily.

Connect to... Chemistry

When a leech feeds on an organism, it may take in and store enough blood to keep itself alive for four months. A leech also produces an anticoagulant while feeding and during the months of digestion. Find out what an anticoagulant is and *infer* how it benefits the leech.

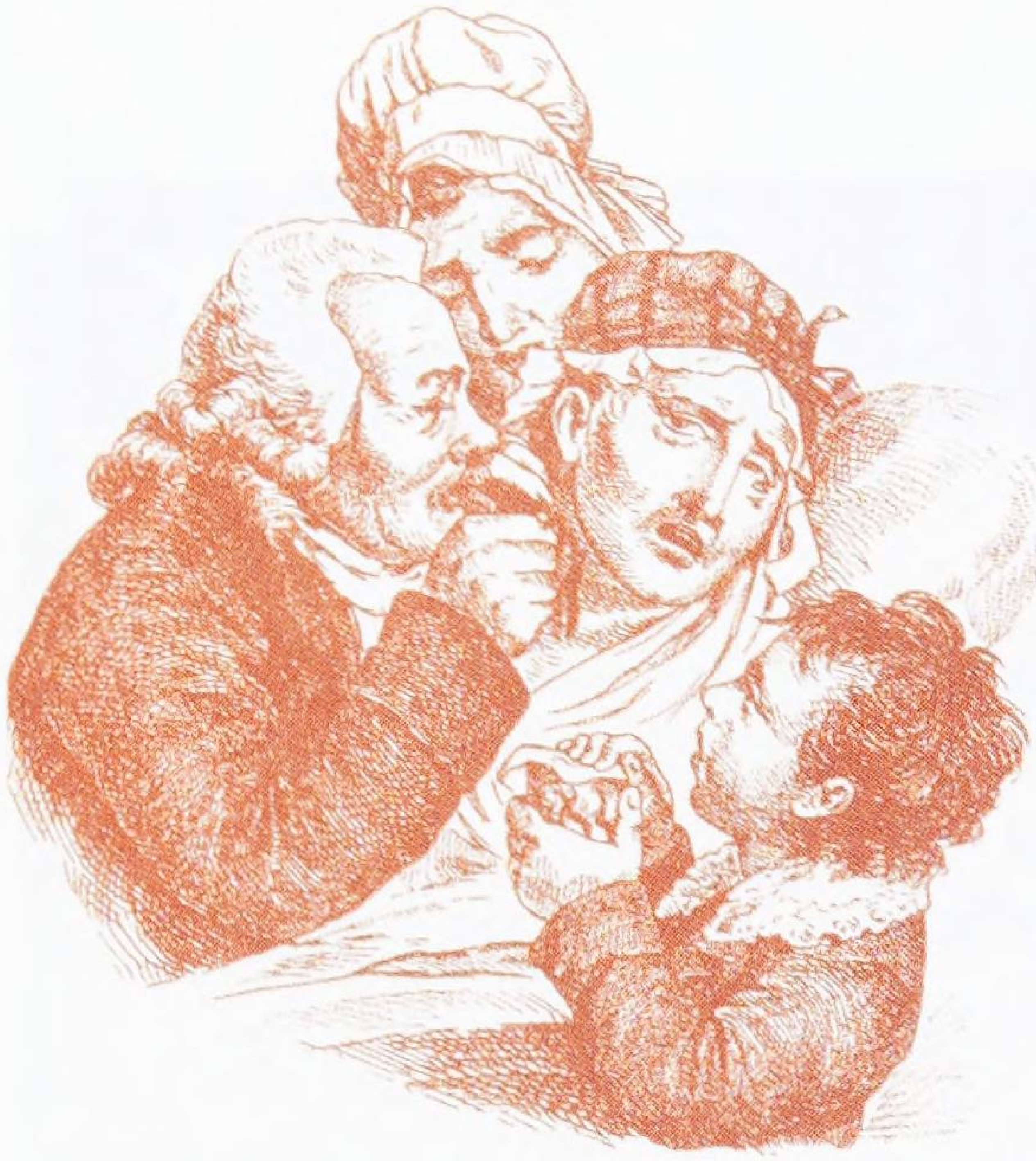
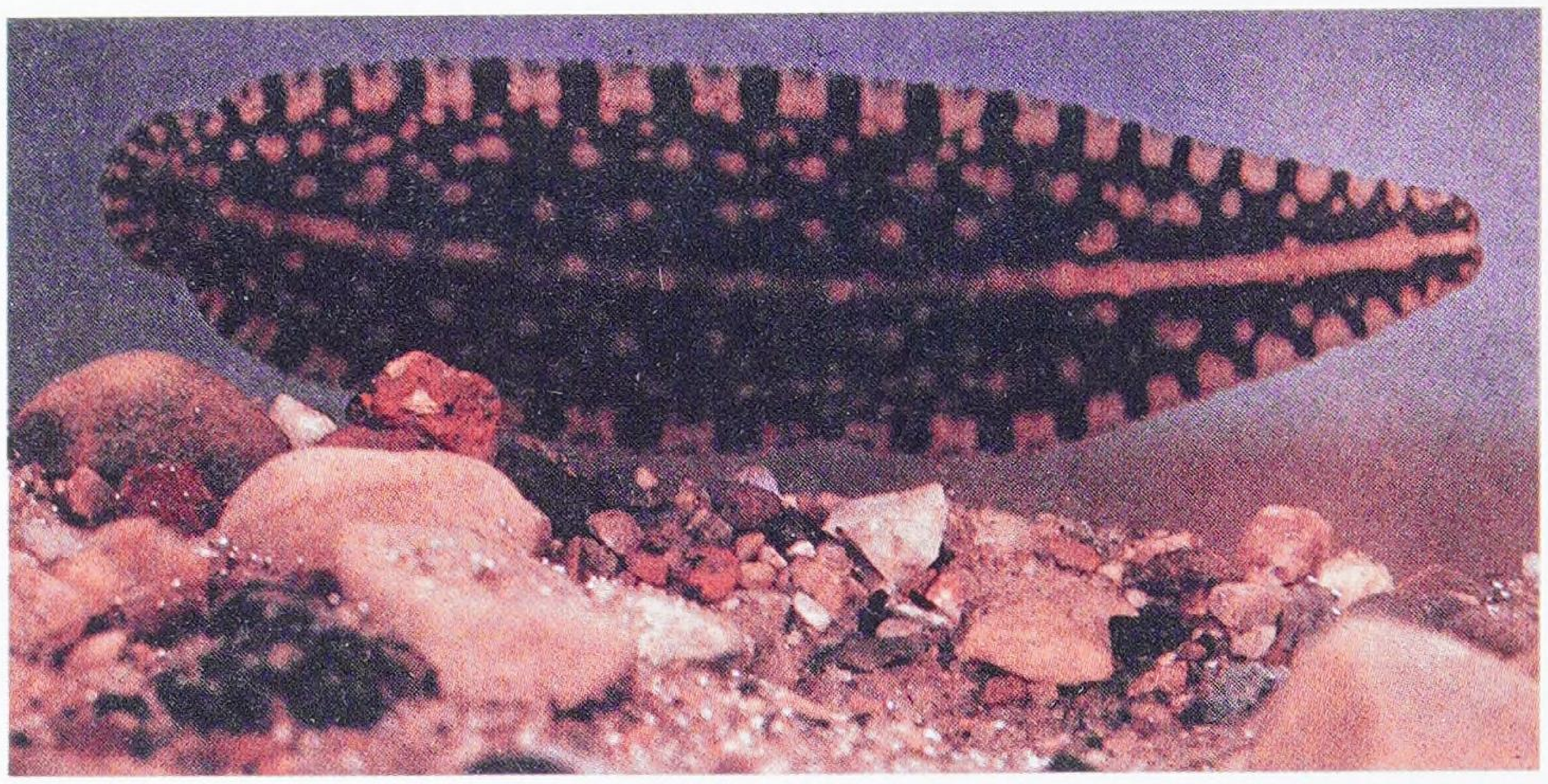


Figure 14-6. Leeches were once used to try to cure sick people.



Before the 1900s, physicians used leeches to drain blood from sick people. They thought that bleeding by leeches would drain away sickness and make the person well. The treatment usually caused patients to become weaker. Sometimes it even killed them.

Evolution of Segmented Worms and Mollusks

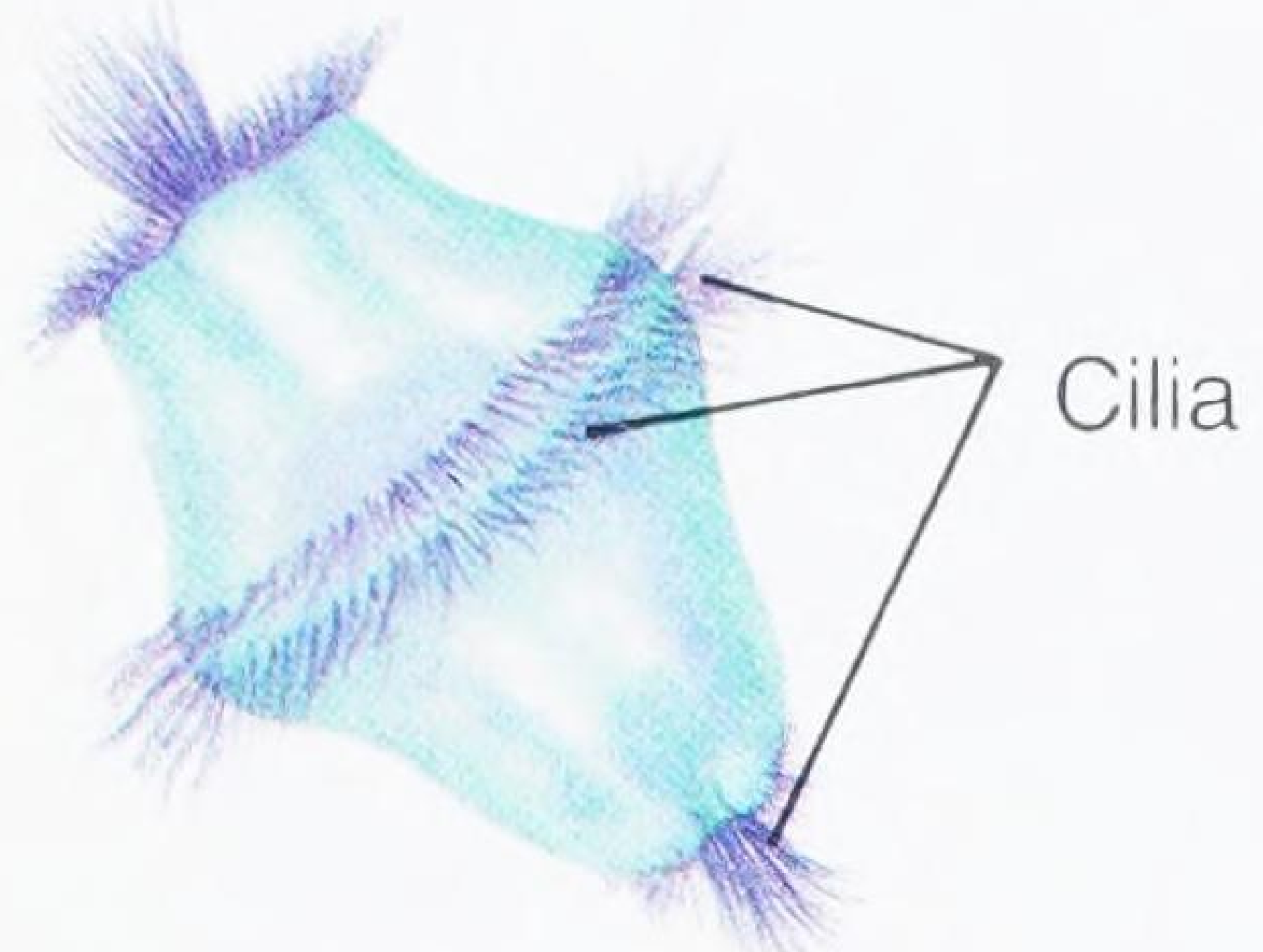


Figure 14-7. Mollusks and segmented worms have the same type of larva.

Scientists think that mollusks and segmented worms share a common ancestor. They were the first of the animal groups to have a body with space for the body organs. In both groups, the first stage of development is a structure that looks like a spinning top with cilia. This structure, a larva, is shown in Figure 14-7. This larva is the best evidence that mollusks and segmented worms share a common ancestor.

SECTION REVIEW

1. What is the most noticeable feature of annelids?
2. Describe how an earthworm feeds and digests its food.
3. How are segmented worms related to mollusks?
4. How are leeches different from earthworms?
5. **Apply:** During dry periods, where are earthworms found in soil? Explain.
6. **Connect to Earth Science:** Why do farmers depend on earthworms that live in the soil of their crop fields?

Skill Builder

☑ Interpreting Scientific Illustrations

Use the diagram in Figure 14-5 to list the body systems of an earthworm and organs in each system. If you need help, refer to Interpreting Scientific Illustrations in the **Skill Handbook** on page 693.

ACTIVITY 14-1

Observing a Segmented Worm

Problem: *How is an earthworm's structure related to its way of life?*

Materials

- live earthworm
- moist paper towels
- shallow pan
- water
- hand lens
- loose soil
- cotton swab
- vinegar

Procedure

1. Wet your hands and remove an earthworm from the container your teacher has provided. **CAUTION:** *Use care when working with live animals.* Keep your hands wet while working with the earthworm. *Observe* the body shape, especially at the ends.
2. Use a hand lens to observe the structure of the earthworm. Use the diagram on page 328 to help you locate the mouth, anus, and clitellum. Estimate the number of body segments.
3. Hold the worm gently between your thumb and forefinger. *Observe* its movements and record them in a data table like the one shown. Use the hand lens to observe the setae on the underside.
4. Touch the anterior and posterior areas of the body with a moist cotton swab. *Record* your observations.
5. Dip a cotton swab in vinegar. Draw a "line of vinegar" on the moist paper towel in front of the earthworm. Record your observations.
6. Place the earthworm on the surface of a thick layer of loose soil in a pan. Record the movements of the worm.
7. Return the earthworm to the place your teacher has provided. Wash your hands.

Data and Observations

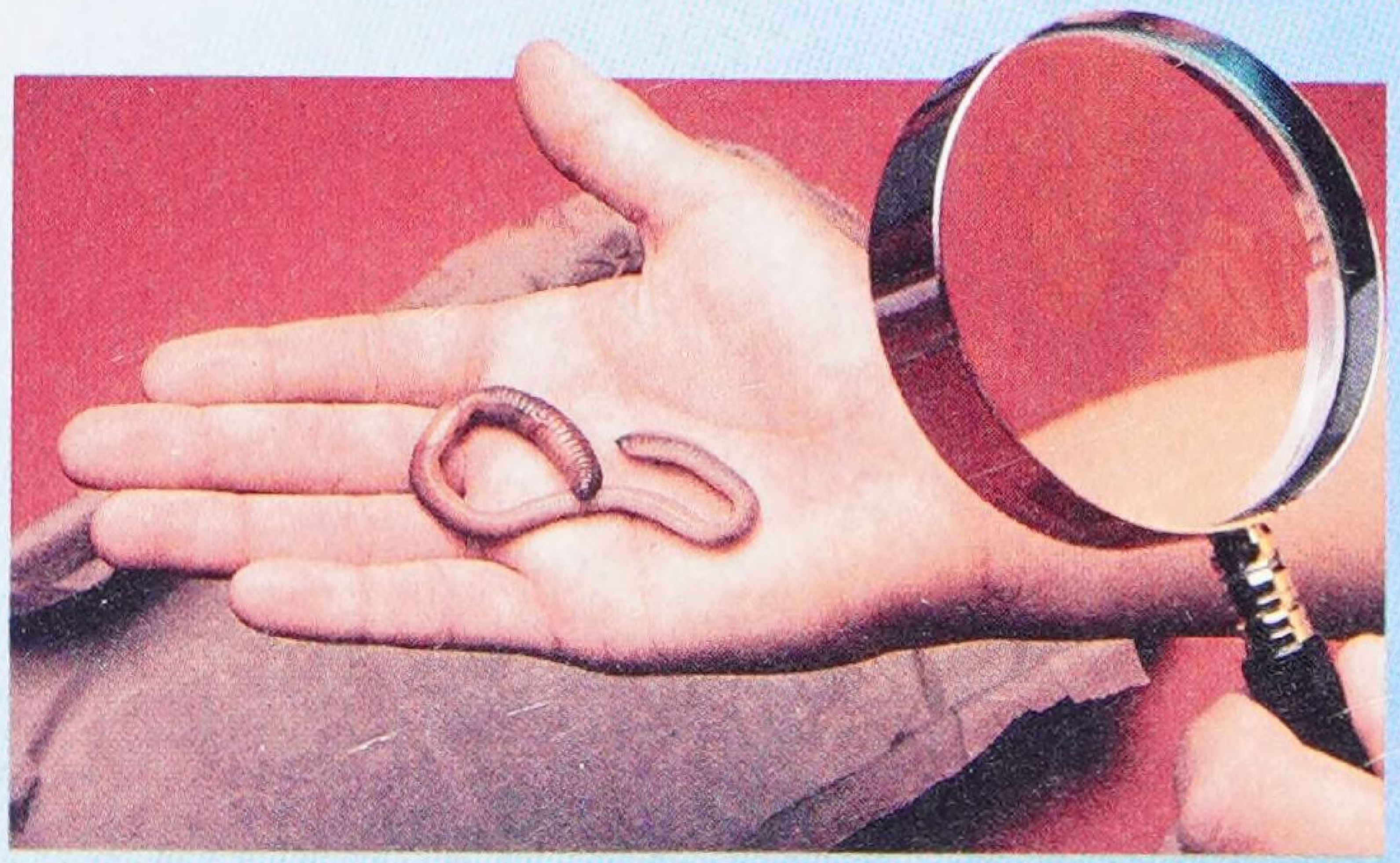
Stimulus	Response
Moist paper towel	
Fingers	
Touch, anterior	
Touch, posterior	
Vinegar	
Soil	

Analyze

1. How many segments does the earthworm have?
2. How do the anterior and posterior differ?
3. Does the earthworm have any visible sense organs?

Conclude and Apply

4. How does the earthworm's response to touch help it to live in soil?
5. What can you *infer* about the usefulness of setae?
6. How does the shape of the body help the earthworm to live in soil?
7. What can you *conclude* about how an earthworm's structure is related to its way of life?



14-3 Arthropods

New Science Words

Arthropoda
appendages
exoskeleton
molting
spiracles
metamorphosis

Objectives

- Identify features used to classify arthropods.
- Relate the structure of the exoskeleton to its function.
- Distinguish between complete and incomplete metamorphosis.

Features of Arthropods

Have you ever swatted at a fly, been bitten by a mosquito, or been stung by a bee? If you have, you've been bugged by an arthropod (AR thruh pahd). The arthropods make up the largest phylum of animals in the animal kingdom. They are adapted to almost every environment on Earth. Insects, shrimp, spiders, and centipedes are all members of the phylum **Arthropoda.**

What are arthropods?

Arthropoda means "jointed foot" and describes the jointed appendages of arthropods. **Appendages** are structures that grow from the body. Your arms and legs are appendages. The jointed appendages of arthropods include legs, antennae, claws, and pinchers.

The bodies of arthropods are divided into segments like those of segmented worms. Because of this, scientists think that arthropods and segmented worms have a common ancestor. The bodies of some arthropods have many segments, whereas others have segments that are fused together to form body regions. Figure 14-8 shows three regions formed by fused segments: the head, the thorax, and the abdomen.

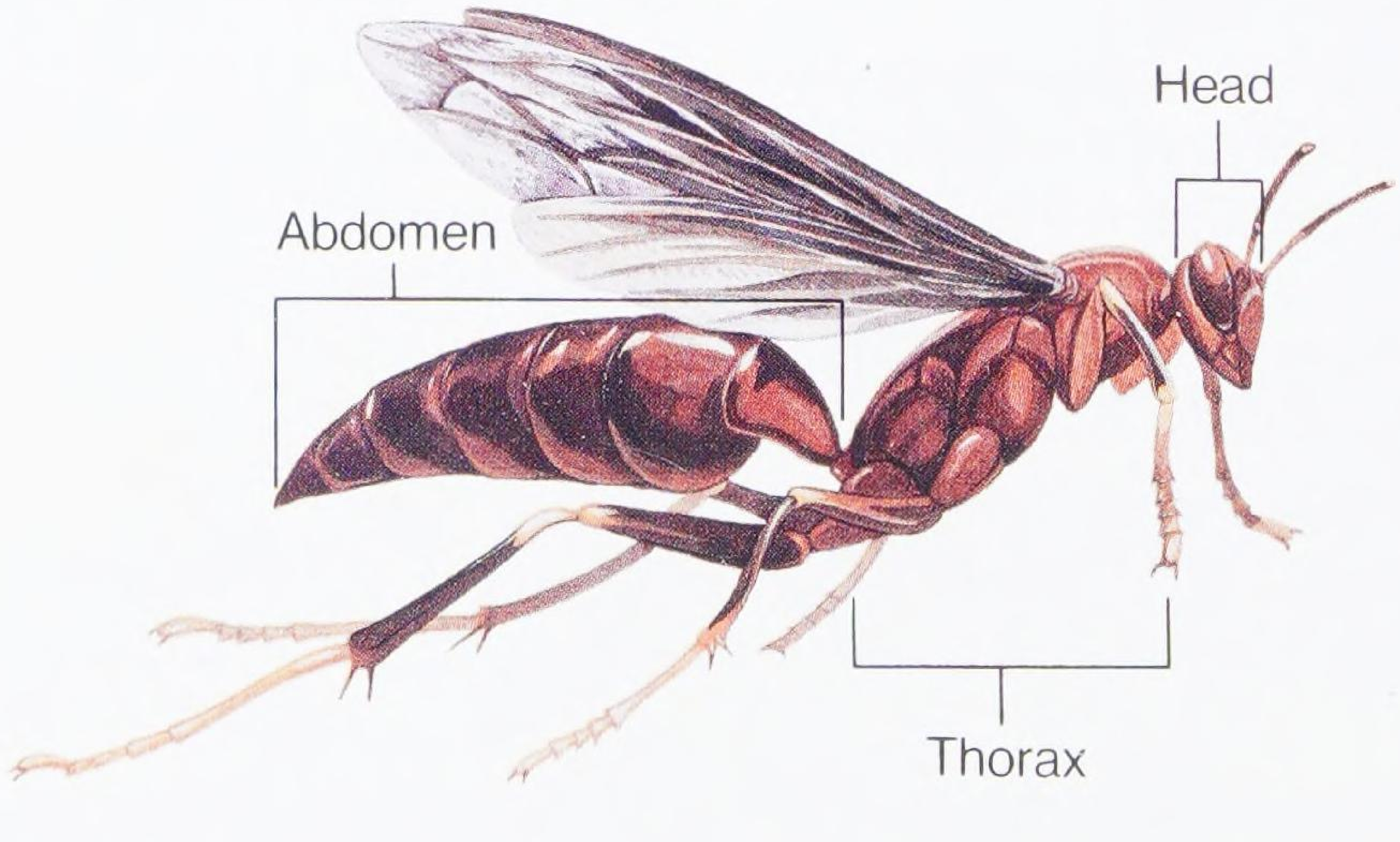


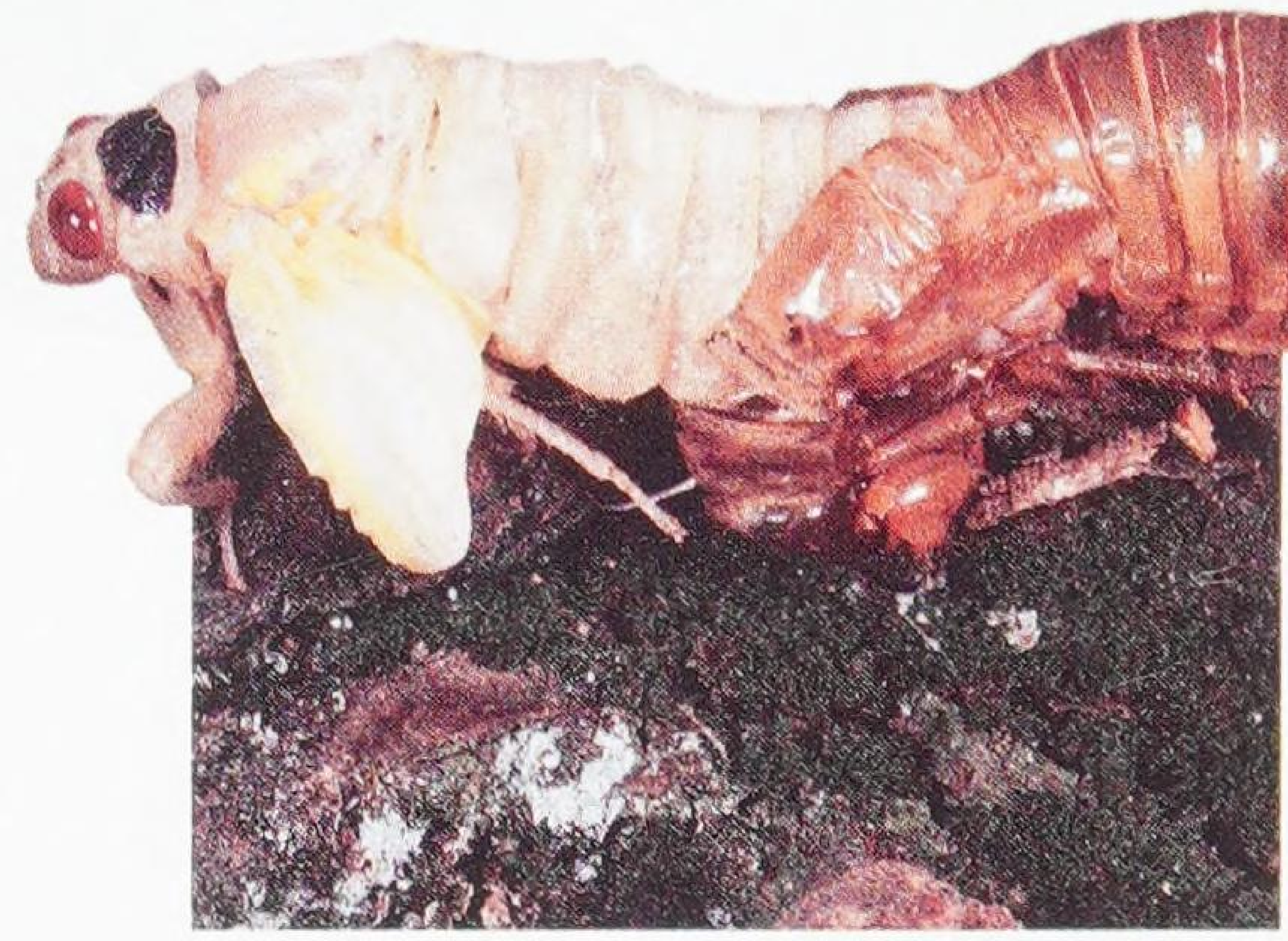
Figure 14-8. The segments of arthropods are fused together to form three regions: the head, the thorax, and the abdomen.

In addition to jointed appendages and segmented bodies, all arthropods have an external covering called the **exoskeleton.** The exoskeleton covers, supports, and protects the body. The lightweight exoskeleton is made of protein and a carbohydrate called chitin (KITE un). This covering also keeps the animal's body from drying out.

The exoskeleton is made of nonliving material, so it can't grow as the animal grows. From time to time, the old exoskeleton is shed and replaced by a new one in a process called **molting.** The new exoskeleton is soft and takes a while to harden. During this time the animal is not well protected from its predators. Many people enjoy eating soft-shelled crabs. The crab has just molted and its new shell hasn't hardened yet.

Arthropods have a body cavity and a digestive system with two openings, a mouth and an anus. They have a nervous system similar to that of annelids but with a larger brain. You will learn about five classes of arthropods in this section.

Figure 14-9. Arthropods molt several times as they grow. In order to molt, this cicada took a large amount of air into its digestive and respiratory systems, causing the body to expand. Expansion cracked the old exoskeleton open.



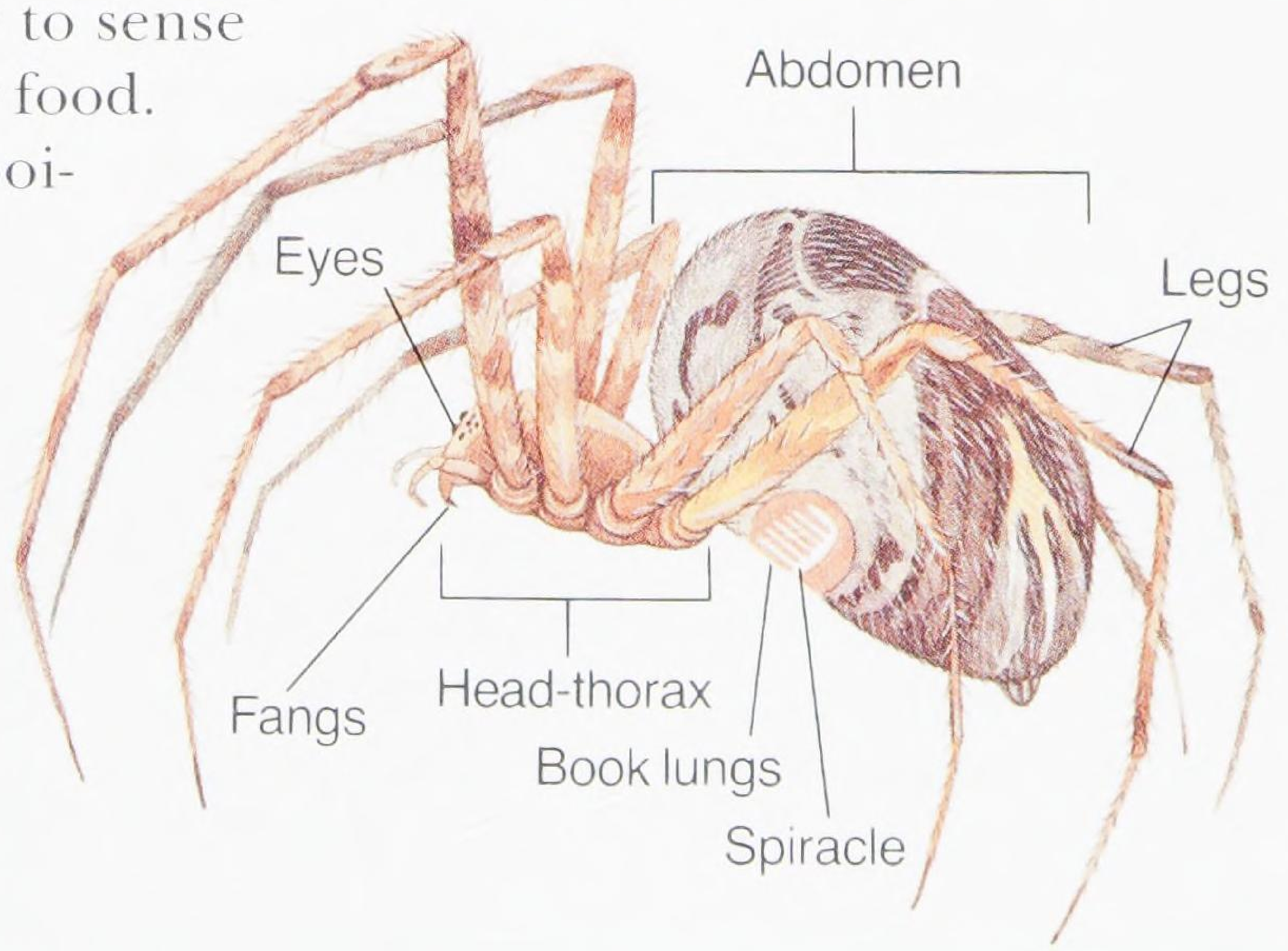
Classes of Arthropods

Arachnids

Spiders, scorpions, mites, and ticks are arachnids (uh RAK nudz). Arachnids are arthropods with two body regions, a head-chest region called the cephalothorax and an abdomen, no antennae, and four pairs of legs. You can tell an arachnid from an insect because the arachnid has eight legs. Arachnids are adapted to kill prey with poison glands, stingers, or fangs. Appendages near the mouth are used to hold food.

The spider in Figure 14-10 is a common arachnid. Spiders have eight simple eyes they use to sense light and darkness. A spider cannot chew food. Using a pair of fangs, a spider injects poison into its prey; the poison paralyzes the prey and turns it into a liquid. The spider then sucks up the liquid. Oxygen and carbon dioxide are exchanged in structures called book lungs. They are called book lungs because they look like the pages of a book. Openings in the abdomen called **spiracles** allow oxygen and carbon dioxide to move into and out of the book lungs.

Figure 14-10. The external structures and book lungs of a common spider



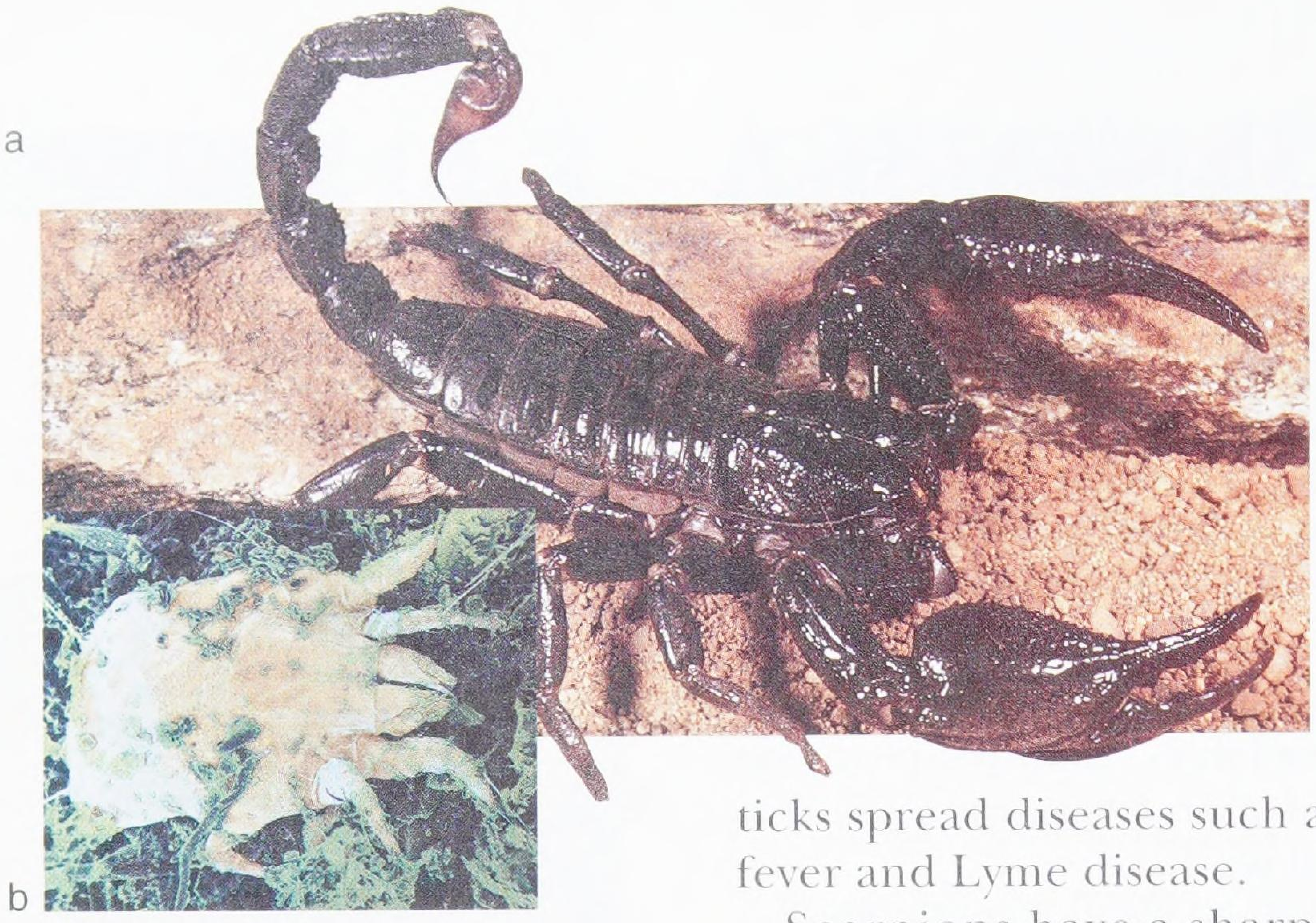


Figure 14-11. Scorpions (a) and housedust mites (b) are both arachnids.

Ticks and mites are arachnids that are parasites. Mites are very tiny. Housedust mites feed on dead skin cells found in the dust on floors and in bedding. There is even a type of mite that lives in the follicles of human eyelashes. Ticks attach to the skin of a host and feed on its blood. Some ticks spread diseases such as Rocky Mountain spotted fever and Lyme disease.

Scorpions have a sharp stinger at the end of the abdomen that contains poison. Scorpions grab their prey with their pinchers and inject venom to paralyze them. The sting of a scorpion is very painful to humans, but it usually is not fatal.

PROBLEM SOLVING

Spinning Spiders

Have you ever looked closely at a spider web? Spiders make these interesting structures using three pairs of openings on the underside of the abdomen called spinnerets. A fluid protein is squeezed out of the spinnerets and hardens into a silk thread when exposed to air.

Some spiders use silk to construct webs to capture prey. Spiders spin two types of silk thread. One type of thread is very strong, whereas the other type is elastic and contains sticky droplets. Garden spiders spin the sticky thread along a spiral line that forms the trapping part of the web.

Spiders use the silk thread for other purposes. Some spiders use silk thread to change habitat. Maybe you've seen a spider glide through the air or lower itself from a tree using a thread. Also, silk threads are used to make cocoons for fertilized eggs or a nest in some species.

Think Critically: Imagine that an insect flies into a garden spider's web. Explain how the insect is captured by the silk, but the spider is able to walk to the prey.

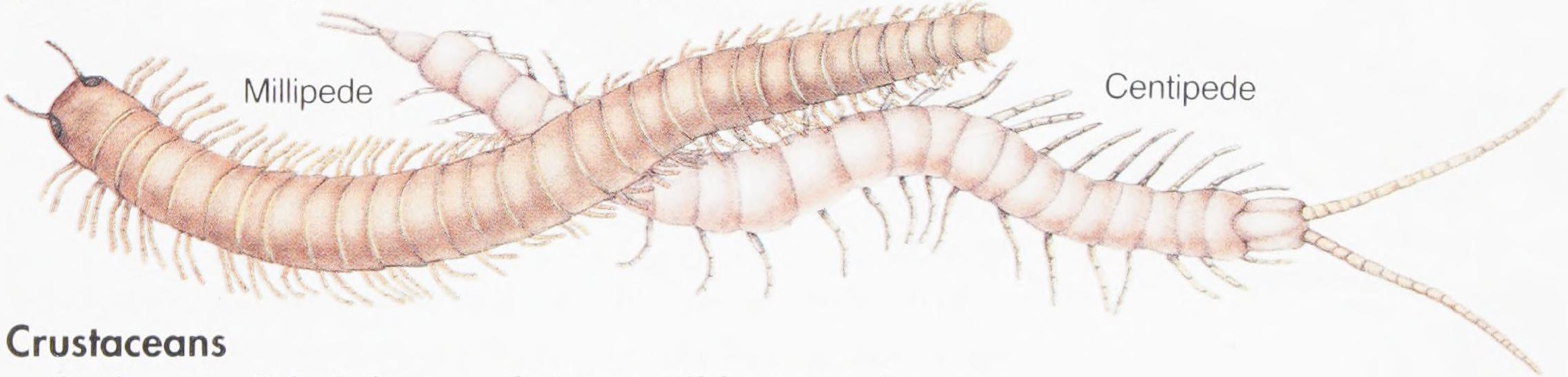
Centipedes and Millipedes

Even though centipedes and millipedes look like worms, you know they are not because worms don't have legs. Centipedes and millipedes make up two classes of arthropods. They have long bodies with many segments, an exoskeleton, jointed legs, antennae, and simple eyes. They live on land in moist environments. Both reproduce sexually and make nests for their eggs. They stay with the eggs until they hatch.

Compare the centipede and millipede below. The centipede has one pair of jointed legs per segment, whereas the millipede has two pairs of legs per segment. Centipedes hunt for their food and have a pair of poison claws used to inject venom into their prey. Centipedes feed on snails, slugs, and worms. Their bites are very painful to humans. Millipedes don't move as quickly as centipedes and feed on plants.

In Your JOURNAL

In your Journal, develop a plan for a new business involving one of the many animals in this chapter. Of course, your plan is to be an ethical and environmentally sound venture. Explain your business plan to your future investors—the class.



Crustaceans

Crabs, crayfish, lobsters, shrimp, pill bugs, and water fleas all belong to the Class Crustacea. Crustaceans are arthropods that have one or two antennae and jaws called mandibles used for crushing food. Most crustaceans live in water, but some, like pill bugs, live on land in moist environments. If you turn over a board or look under some leaves in your yard, you are sure to find a pill bug.

The crayfish in Figure 14-12 is a typical crustacean. Although some crustaceans have three body regions, the crayfish has a head and thorax joined to form one region.

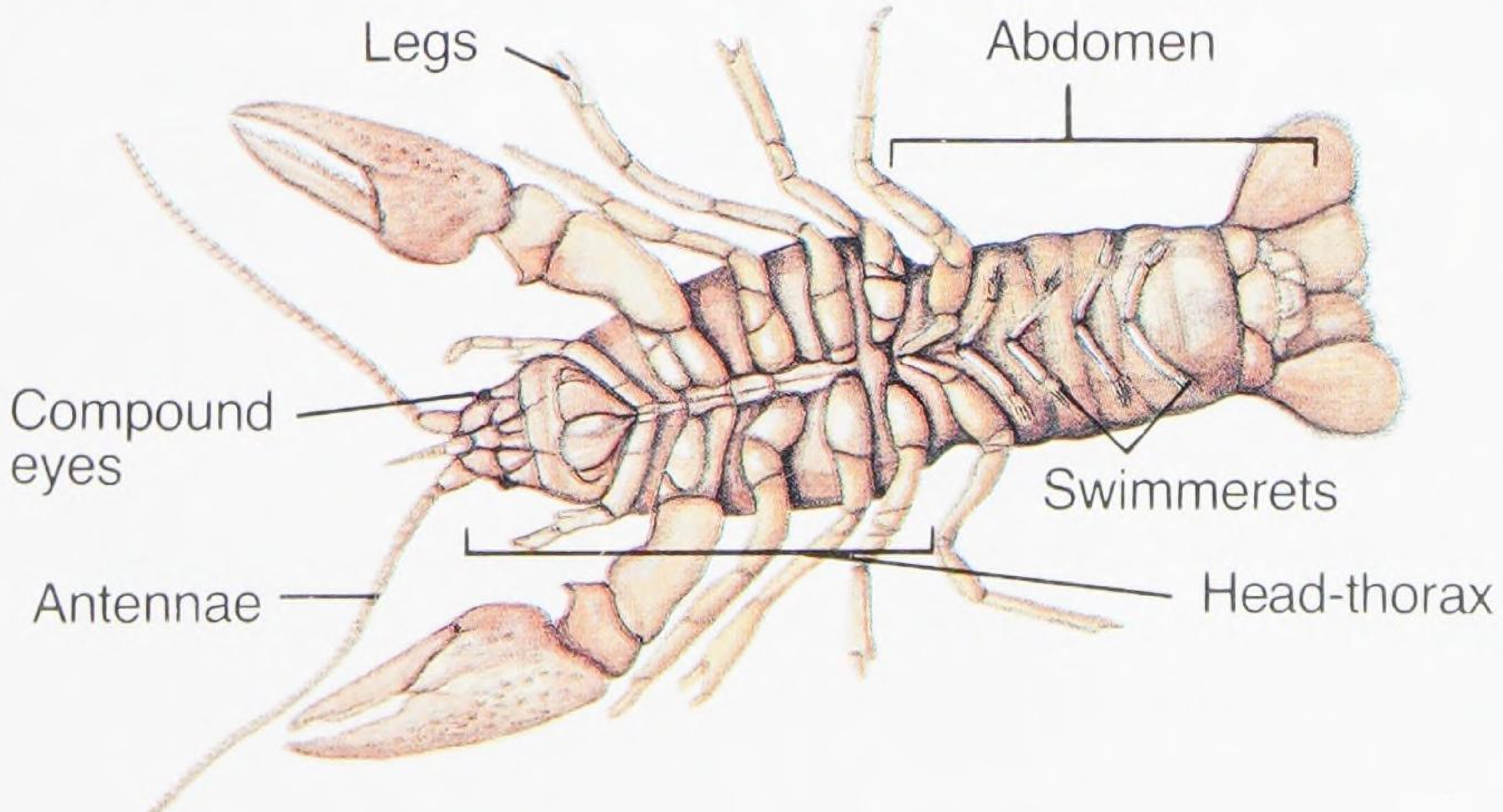


Figure 14-12. All crustaceans have body structures similar to those of a crayfish. Here you can see the features of the ventral surface of the crayfish.

Crustaceans have many pairs of legs. The first pair of legs are claws that catch and hold food. The other four pairs are walking legs. The five pairs of appendages on the abdomen are swimmerets. They help the crustacean move and are used in reproduction. The swimmerets also force water over the feathery gills that crustaceans use for breathing. If a crustacean happens to lose an appendage, it can grow back, or regenerate, the lost part.

Barnacles are crustaceans very different in form from the others. They have a very hard, stony shell and spend their lives cemented to boats, piers, or animals such as whales.

Science and READING

Insects are an important food source for many species of bats. In turn, the bats help control the populations of several types of insects, such as mosquitoes. Research the types of insects bats feed on. Find out the areas of the country where bats are important in controlling insect populations.

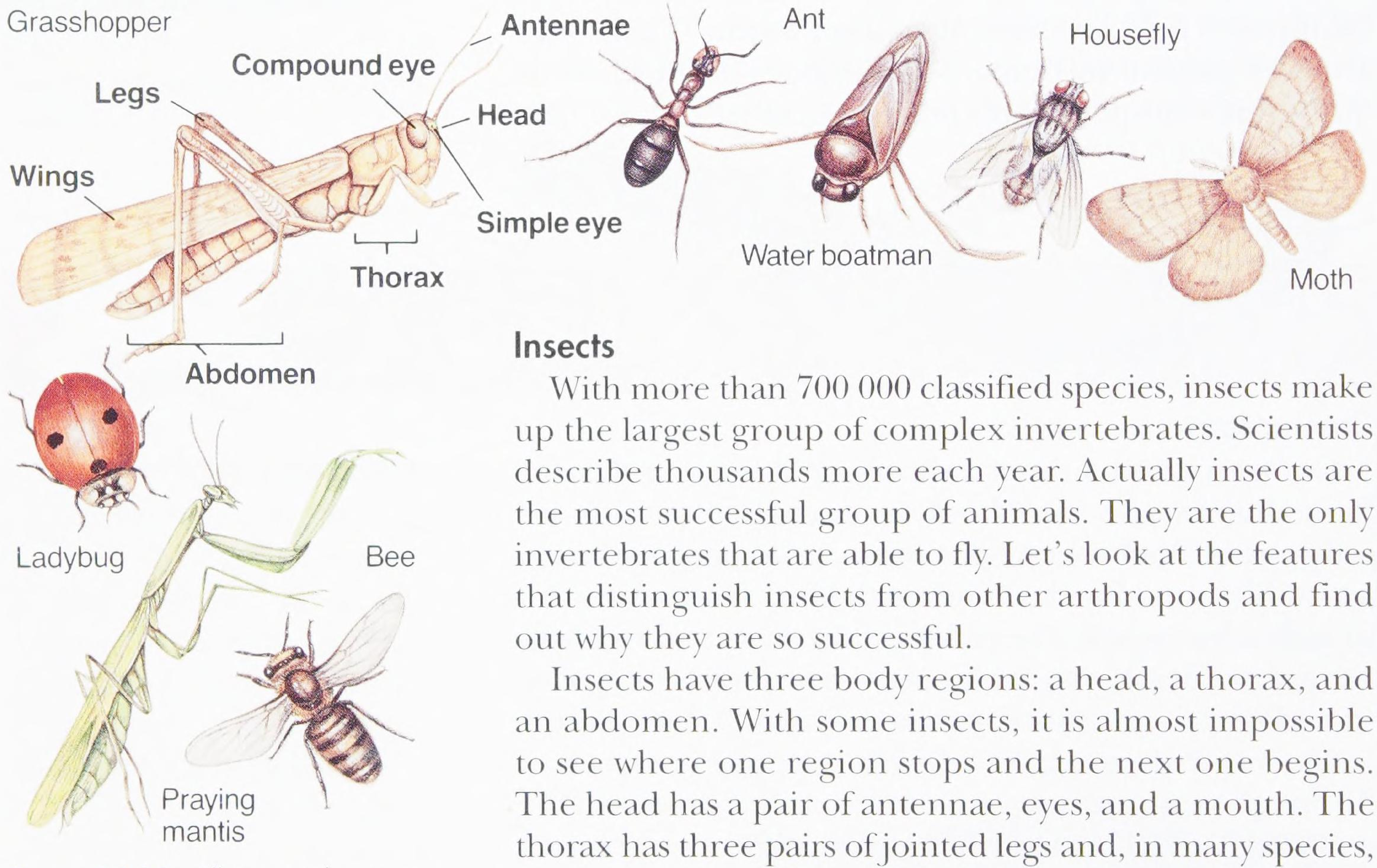


Figure 14-13. All insects have six legs, a head, a thorax, and an abdomen. They also have two pairs of wings, one pair of antennae, and a pair of compound eyes.

Insects

With more than 700 000 classified species, insects make up the largest group of complex invertebrates. Scientists describe thousands more each year. Actually insects are the most successful group of animals. They are the only invertebrates that are able to fly. Let's look at the features that distinguish insects from other arthropods and find out why they are so successful.

Insects have three body regions: a head, a thorax, and an abdomen. With some insects, it is almost impossible to see where one region stops and the next one begins. The head has a pair of antennae, eyes, and a mouth. The thorax has three pairs of jointed legs and, in many species, one or two pairs of wings. The abdomen is divided into 11 segments and has neither wings nor legs attached to it.

Most insects have one or two pairs of wings. Flies have one pair. Some insects such as silverfish and fleas don't have wings. Flying enables insects to find new places to live, new food sources, and mates. It also helps them escape from their enemies.

The head of most insects has simple and compound eyes and a pair of antennae. Simple eyes are used to detect light and dark. Compound eyes contain many lenses and detect some colors and movement. The antennae are used for touch and smell.

Insects have open circulatory systems similar to mollusks. The open circulatory system carries digested food to cells and removes wastes. The almost colorless blood does not carry oxygen. As in arachnids, insects have spiracles on the abdomen and thorax that take in air and expel waste gases. You can see that insects have systems for digestion, reproduction, and removing wastes.

Insects reproduce sexually. Females lay thousands of eggs but only a fraction of the eggs develop into adults. Think about how overproduction ensures that the species will continue.

Many species of insects and other animals that hatch from fertilized eggs go through a series of changes in body form to become adults. This series of changes is called **metamorphosis.** Metamorphosis is controlled by chemicals secreted by the body of the animal. There are two kinds of metamorphosis—complete and incomplete.

Most insects, including butterflies, beetles, ants, bees, moths, and flies, develop through complete metamorphosis. The four stages of development are egg, larva, pupa, and adult. A fertilized egg hatches into a wormlike larva stage. Maggots and caterpillars are larvae. The larva spends its time eating and growing before forming a shelter called a cocoon or chrysalis and going into a resting stage called the pupa. Inside, the larva changes and develops into an adult in a process that is little understood. The cocoon eventually opens and the adult comes out.

MINI-Lab

What type of metamorphosis do fruit flies undergo?

Obtain from your teacher a vial containing food and fruit flies in various stages of metamorphosis. *Identify* and draw all the stages of metamorphosis you see. Observe the vial every day for two weeks and record your observations. What type of metamorphosis do fruit flies undergo? About how long does each stage last? In what stages are the flies the most active?

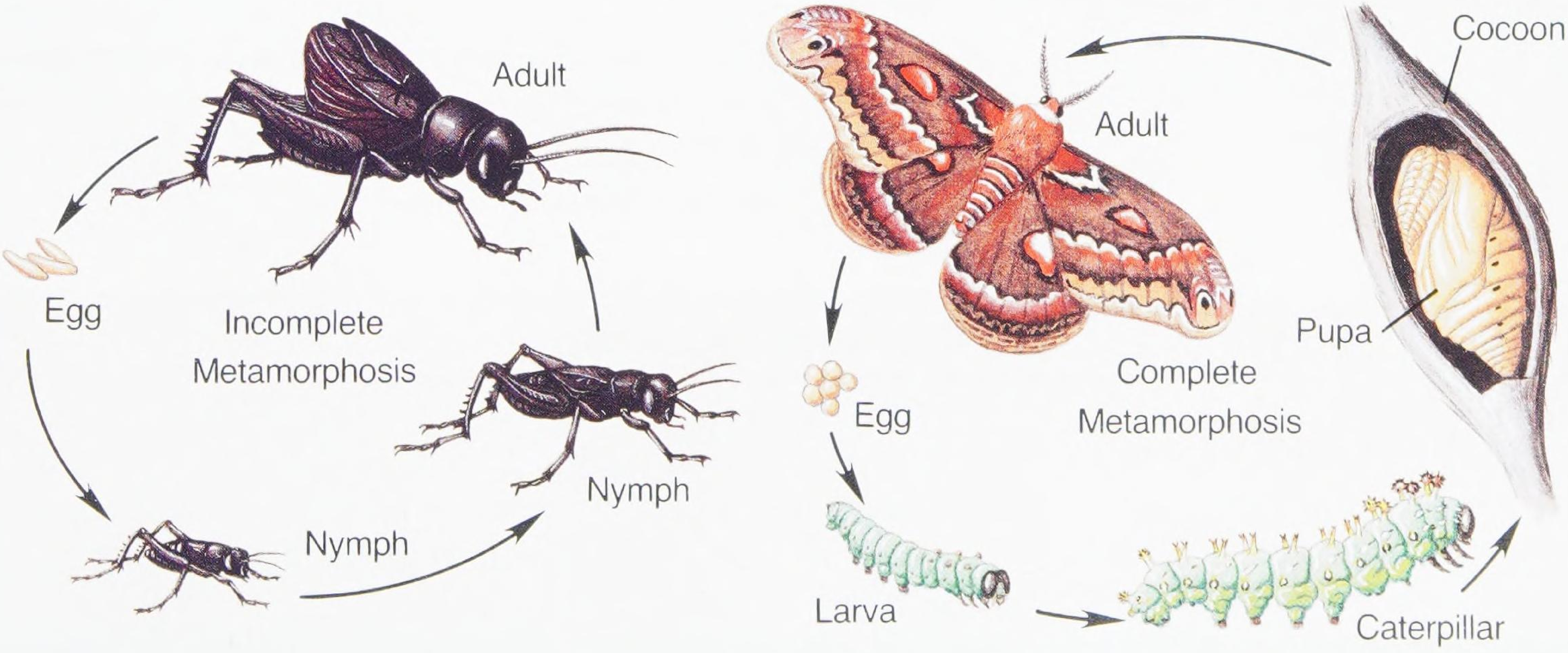


Figure 14-14. Butterflies and moths undergo complete metamorphosis. A moth forms a cocoon. A butterfly forms a chrysalis. Crickets undergo incomplete metamorphosis.

Grasshoppers, silverfish, lice, and crickets develop through incomplete metamorphosis. The three stages of development are egg, nymph, and adult. The fertilized egg hatches into a nymph that looks like a small adult, but without wings. A nymph molts several times before reaching the adult stage.

Adaptations such as an exoskeleton with wings and jointed appendages allow insects to live on land and to fly. Insects adapt to new environments rapidly because they have short life spans. Natural selection takes place more quickly in insect populations than in organisms that take longer to reproduce. Small size allows them to live in a wide range of environments, use a small amount of food, and hide from their enemies. Many species of insects can live in the same area and not compete with one another for food.

Many people think the world would be better off without insects. They cause problems for people by eating crops, clothing, and wood in buildings. Some insects spread diseases. But it would be a serious mistake to think that we could live without them, for they are also helpful. They pollinate flowering plants that produce fruits and vegetables. They feed on decaying wood, and produce honey and other useful products.

Connect to... Chemistry

Honeybees make honey by sucking up nectar from flowers and storing it in their stomachs where other chemicals are added to it. When the stomach is filled, the honeybee returns to the hive and puts the nectar into an empty cell. In the honeycomb, the water in the nectar evaporates and the chemicals turn the nectar into honey. Find out what chemical makes up the major part of honey.

SECTION REVIEW

1. What are three features of all arthropods?
2. What are the advantages and disadvantages of an exoskeleton?
3. Describe the stages in complete metamorphosis and the stages in incomplete metamorphosis.
4. **Apply:** Choose an insect you are familiar with and explain how it's adapted to its environment.
5. **Connect to Physics:** Find out how male crickets use sound to attract females.

Skill Builder

Concept Mapping

Make a concept map showing the events in the complete metamorphosis of an insect. Make another concept map showing the events in incomplete metamorphosis. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

ACTIVITY 14-2

Observing a Crayfish

Problem: *How does a crayfish use its appendages?*

Materials

- crayfish in a small aquarium
- stirrer
- uncooked ground beef

Procedure

1. Your teacher will provide you with a crayfish in an aquarium. **CAUTION:** *Use care when working with live animals. Leave the crayfish in the aquarium while you do the activity.*
2. Touch the crayfish with the stirrer. How does the body feel?
3. *Observe* the crayfish move in the water. How many body regions does it have? Name the regions. Use the diagram on page 335 to help you. How many appendages does it have on each body region? What is the function of the appendages? Record your answers in a data table like the one shown.
4. Observe the compound eyes. On which body region are they located?
5. Drop a small piece of ground beef into the aquarium and observe how the crayfish eats.
6. Return the crayfish and aquarium to the place your teacher has assigned. Wash your hands.

Analyze

1. Describe the texture of the body of the crayfish.
2. How many body regions does it have?
3. How many appendages are located on each body region?
4. What structures does the crayfish use to get food?

Conclude and Apply

5. *Infer* how the location of the eyes is an advantage for the crayfish.
6. How does the structure of the claws aid in getting food?
7. What can you *infer* about the exoskeleton and protection?

Data and Observations

Body Region	Appendages	Function

SCIENCE & SOCIETY

14-4 Pesticides

New Science Words

pesticide

Objectives

- Describe the importance of pesticides in agriculture.
- Identify the impacts of pesticides on the environment.

Insect Pests?

What's your first reaction when you see insects? Are you inclined to avoid them? Many people are! We typically view insects as pests that are better dead than walking around in our homes. Most insects are harmless. In fact, many, such as the praying mantis, are beneficial. These insects eat harmful insects. On the other hand, farmers and gardeners often find it necessary to destroy insects that damage crops and ornamental plants. Many farmers would not have successful crop yields without the use of pesticides. **Pesticides** are chemicals that kill undesirable plants and insects. It is estimated that for every $3 million spent on pesticides, about $12 million is returned in additional crops. In addition, the price of pesticides has increased much more slowly than the price of other farm expenses. This makes pesticides a very smart investment for farmers.

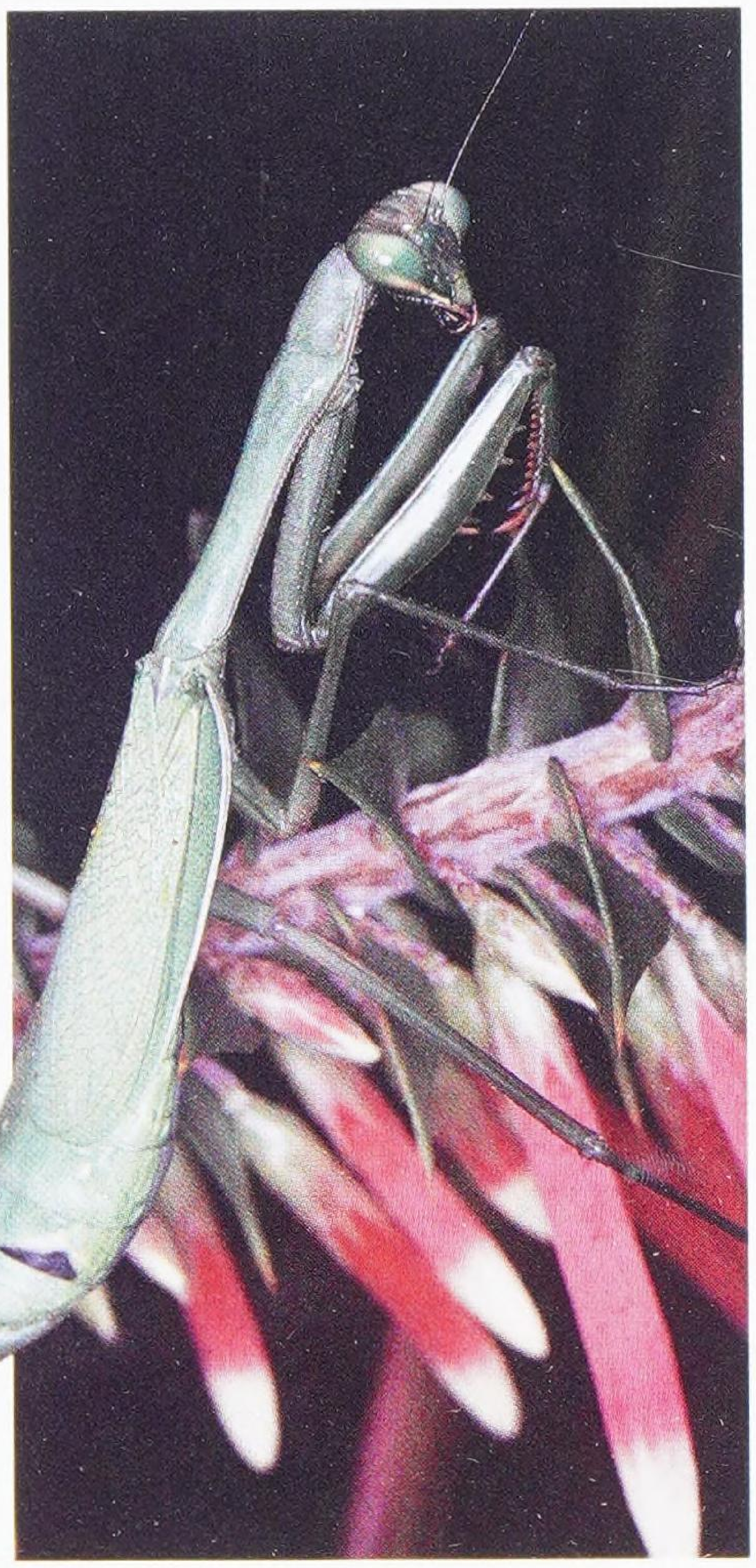


Figure 14-15. The praying mantis is a beautiful and helpful insect.

Although pesticides are very beneficial to farmers, the environmental damage caused as a result of pesticides is thought to be very great. Studies show that very little of the pesticide applied to crops actually reaches the target organism. Instead, about 99 percent of the pesticide winds up in the soil, water, and air. Here, it is not only the harmful insects that are killed, but most of the nation's 200 000 species of plants and animals are also affected. For example, animals that feed on the plant sap or tissue may come in contact with the pesticides. Some larger animals, including birds and mammals, may either come in direct contact with the pesticide or feed on plants and animals that have been contaminated. One study showed that the pesticide DDT accumulates in the environment and can contaminate organisms. DDT is a colorless, odorless pesticide that is toxic to many animals. DDT is no longer in use in the United States. The study showed that in soil containing

10 parts per million of DDT, earthworms contained 141 parts per million of DDT, and robins that fed on those worms contained 444 parts per million in their brain tissues. It is estimated that there are about 45,000 human poisonings due to pesticides every year.

Pesticides that are sprayed over great distances, especially with airplanes, cause much pollution in the air. These vapors are easily inhaled by humans. The soil is the primary place for toxins to accumulate because pesticides often miss the target plant or drip off the plant into the soil. Although very little pesticide is applied directly to the water system, large amounts of pesticides ultimately reach rivers, lakes, and streams, due to the runoff of pesticides in drainage from agricultural fields. Human water supplies are very likely to be contaminated from such runoff.

EcoTip

Flea collars, sprays, dips, and powders often put poisons in the environment. Instead of using these items, comb your pet often with a flea comb and bathe it regularly with a nontoxic shampoo.

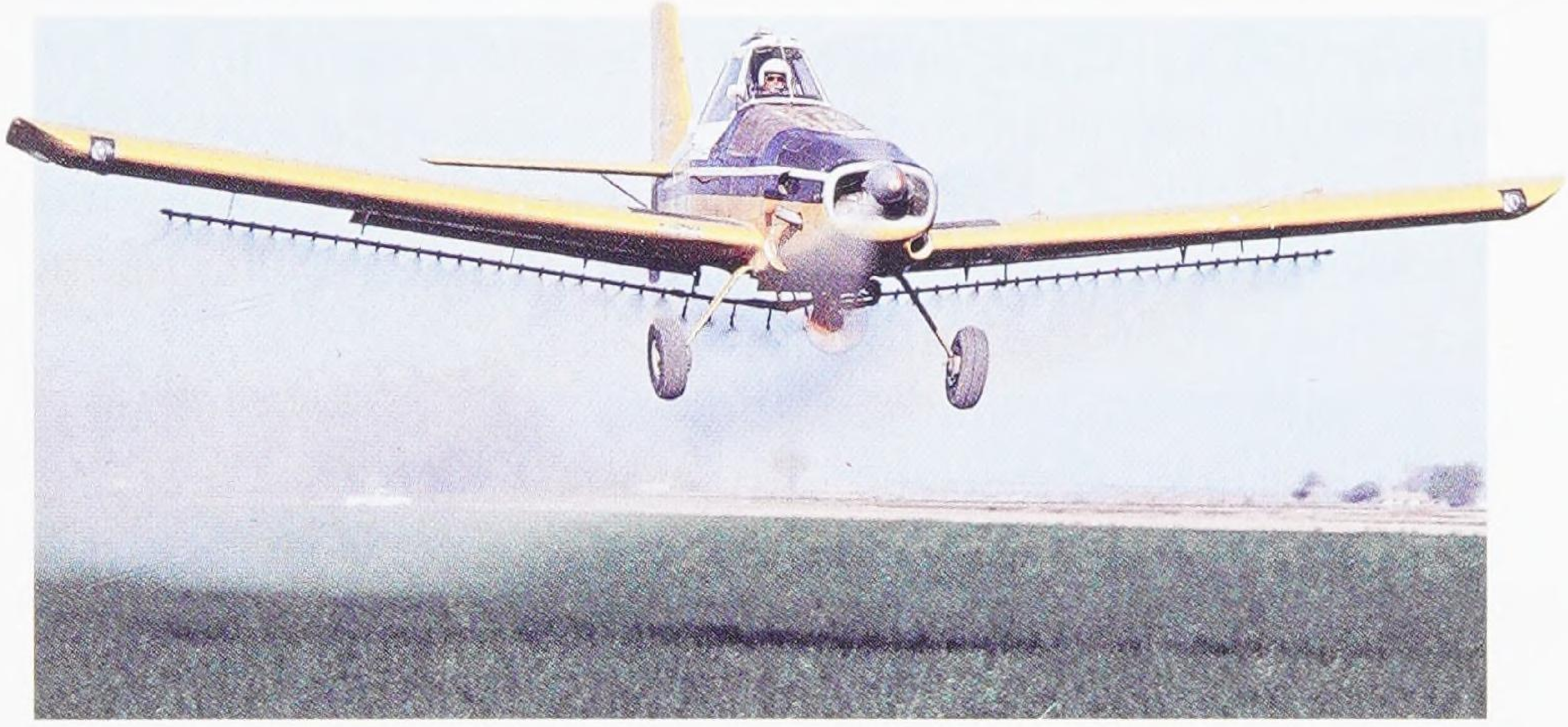


Figure 14-16. Planes are used to spray crops with pesticides.

SECTION REVIEW

1. Why are pesticides so important to our economy?
2. What are the current problems with pesticide application methods?

SCIENCE & SOCIETY

You Decide!

Our society has gained much from pesticides, but are we paying for them with our health? Can some alternative solution be reached? Improved application methods may prevent some of the problem. Use of chemicals that break down easily with the help of sunlight, water, and biological action may also be an option. Even if these solutions are able to cut the current problem in half, should we still continue to use pesticides? Can we live without them?

14-5 Echinoderms

New Science Words

echinoderms
water-vascular system
tube feet

Objectives

- Identify the features of echinoderms.
- Describe how sea stars get and digest food.

Features of Echinoderms

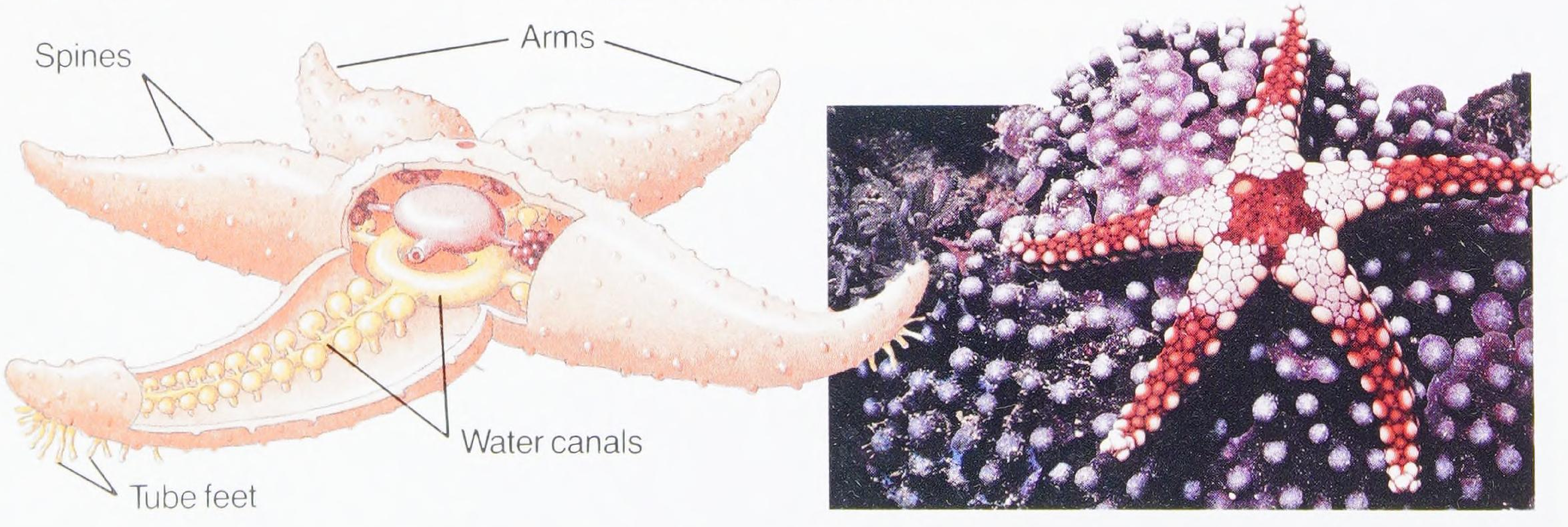
Unless you live near the ocean, you may not have seen an echinoderm, but most of you know what a sea star is. Sea stars, sea urchins, sand dollars, and sea cucumbers are all echinoderms (ih KI nuh durmz). **Echinoderms** are spiny-skinned invertebrates that live on the ocean bottom. The name *echinoderm* means "spiny-skin." The spiny part refers to the spines that cover the outside of these animals. Their bodies are supported and protected by an internal skeleton made of calcium plates. The plates are covered by the thin, spiny skin.

A unique characteristic shared by all echinoderms is a water-vascular system. The **water-vascular system** is a network of water-filled canals. Thousands of tube feet are connected to this system. **Tube feet** act like strong suction cups and help the animal move, feed, get oxygen, and get rid of waste. Look at the tube feet shown in Figure 14-18. Another very obvious trait of echinoderms is their radial symmetry. The bodies of echinoderms can be divided into five sections all located around a central point. Let's look more closely at one of the most well known echinoderms, a sea star.

Connect to... Earth Science

Scientists have found many echinoderm fossils from the Cambrian period but few fossils of other species that lived during the Cambrian period. *Infer* what adaptation might explain the large number of fossilized echinoderms.

Figure 14-17. Sea stars and all other echinoderms have a water-vascular system that allows them to move, eat, get oxygen, and get rid of waste.



Sea Stars

If you have ever pried open the shell of an oyster or a clam, you know it's not an easy job. Sea stars feed on these mollusks. Sea stars have five or more arms arranged around a central point. These arms are lined with thousands of tube feet. The sea star wraps its arms around a mollusk and uses the suction power of its tube feet to open the shell.

Figure 14-19 on page 344 shows a sea star using its tube feet to open a clam. Once the shell is open slightly, the sea star turns its stomach inside out, pushes it through its mouth, and surrounds the soft body of the mollusk. The stomach secretes enzymes that digest the animal. Then when the meal is over, the sea star takes the stomach out of the clam shell and pulls it back inside its own body.

Sea stars reproduce sexually by releasing eggs and sperm into the water. Females can produce 200 000 eggs in one season. They also reproduce asexually by regeneration. If a sea star loses an arm, it can grow a new one. If enough of the arm is lost, the arm itself can grow into a whole new sea star.

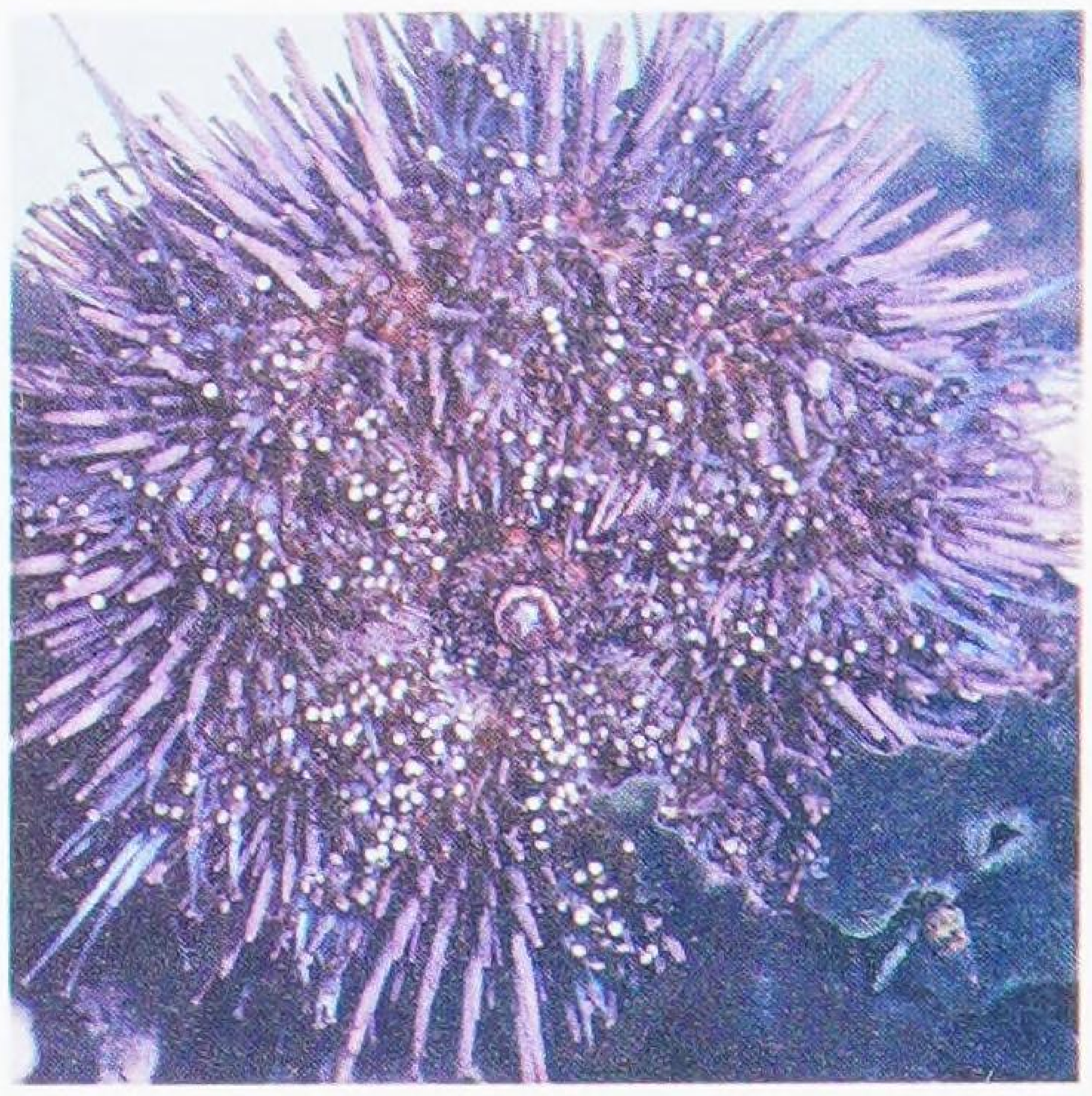


Figure 14-18. All echinoderms have tube feet. This photograph shows the tube feet on the underside of a sea urchin.

Table 14-1

OTHER ECHINODERMS

Brittle Stars

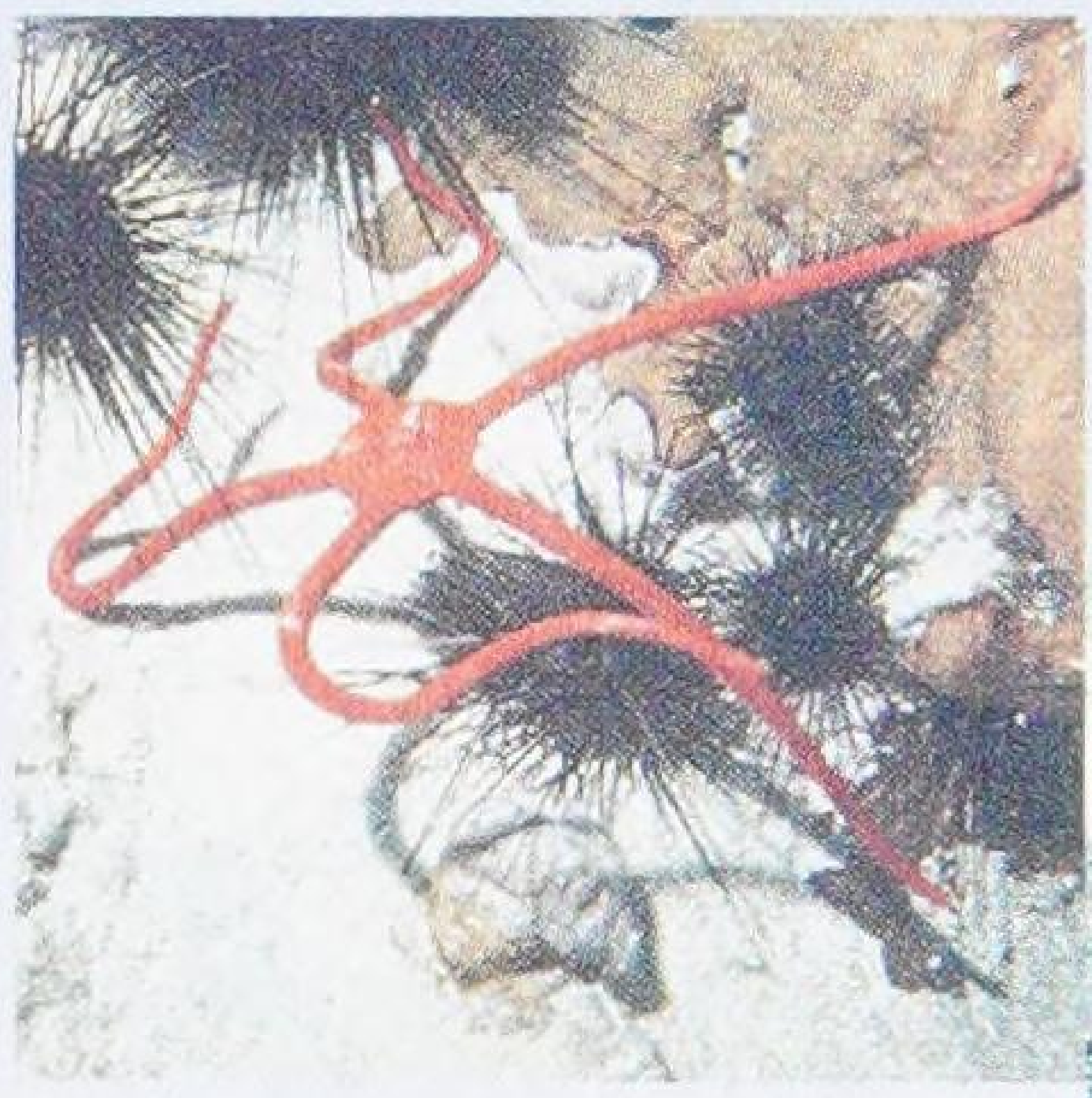
Brittle stars are very secretive echinoderms. They live hidden under rocks or litter on the ocean floor. They move much more quickly than sea stars and break off their arms as a defense when disturbed. The broken parts are quickly regrown.

Sea Urchins and Sand Dollars

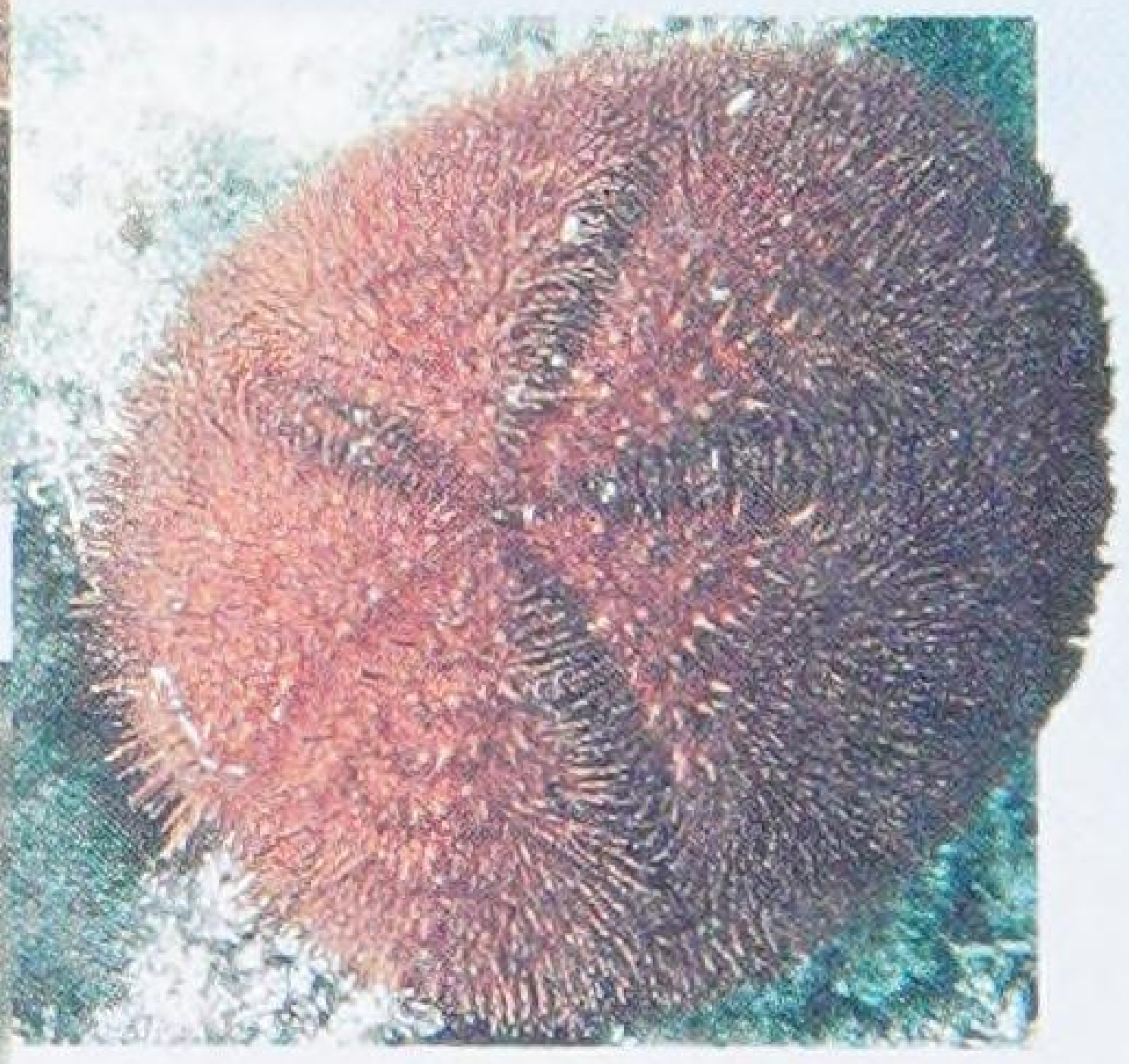
Sea urchins and sand dollars make up another class of echinoderms. Both have a skeleton made of calcium carbonate plates, and both are covered with spines. Sand dollars are very flat and covered with small, fine spines, whereas sea urchins are round and covered with longer spines.

Sea Cucumbers

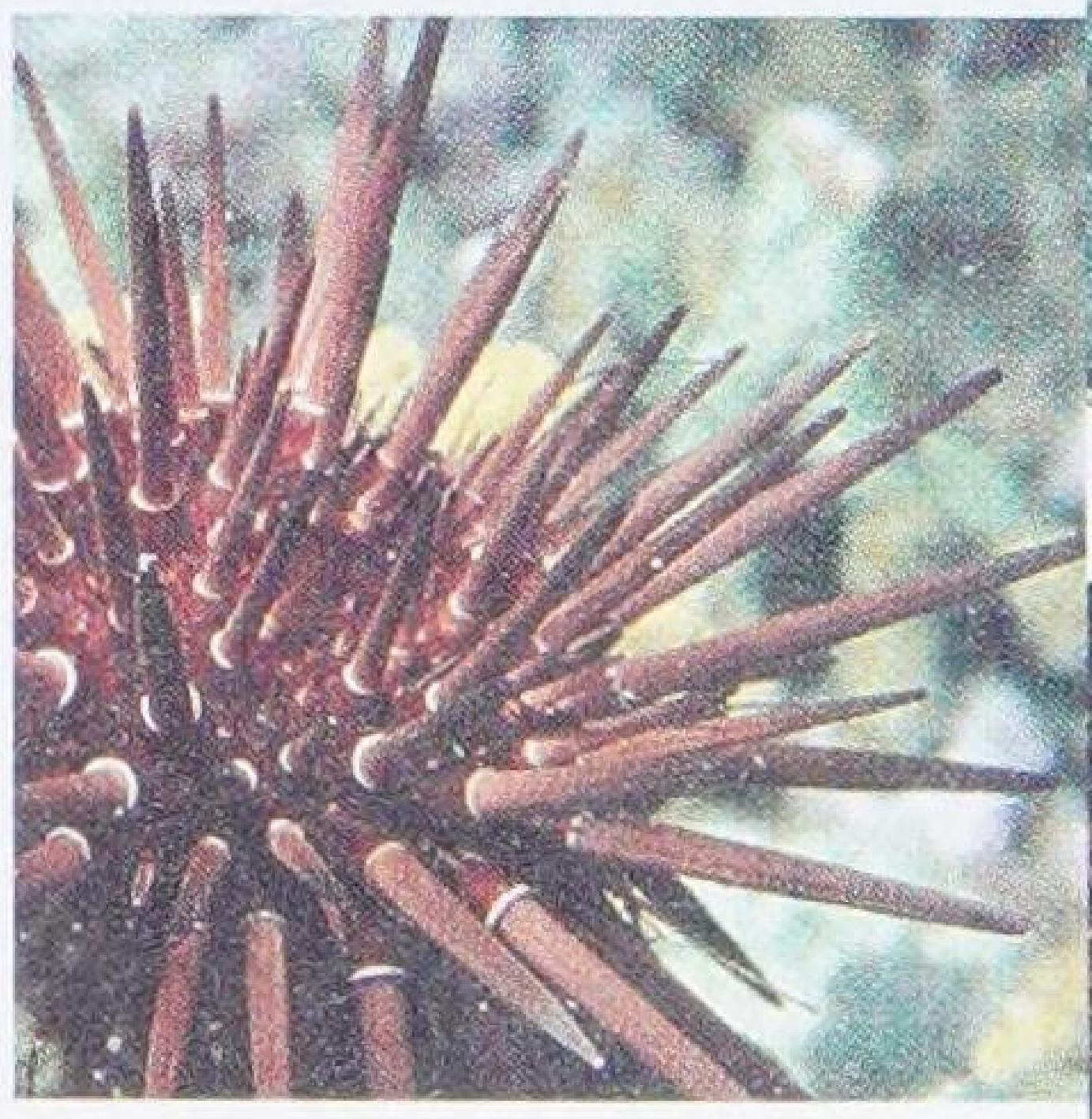
Sea cucumbers are soft-bodied echinoderms with a leathery covering. They have tentacles around the mouth and rows of tube feet on the ventral, or bottom, side.



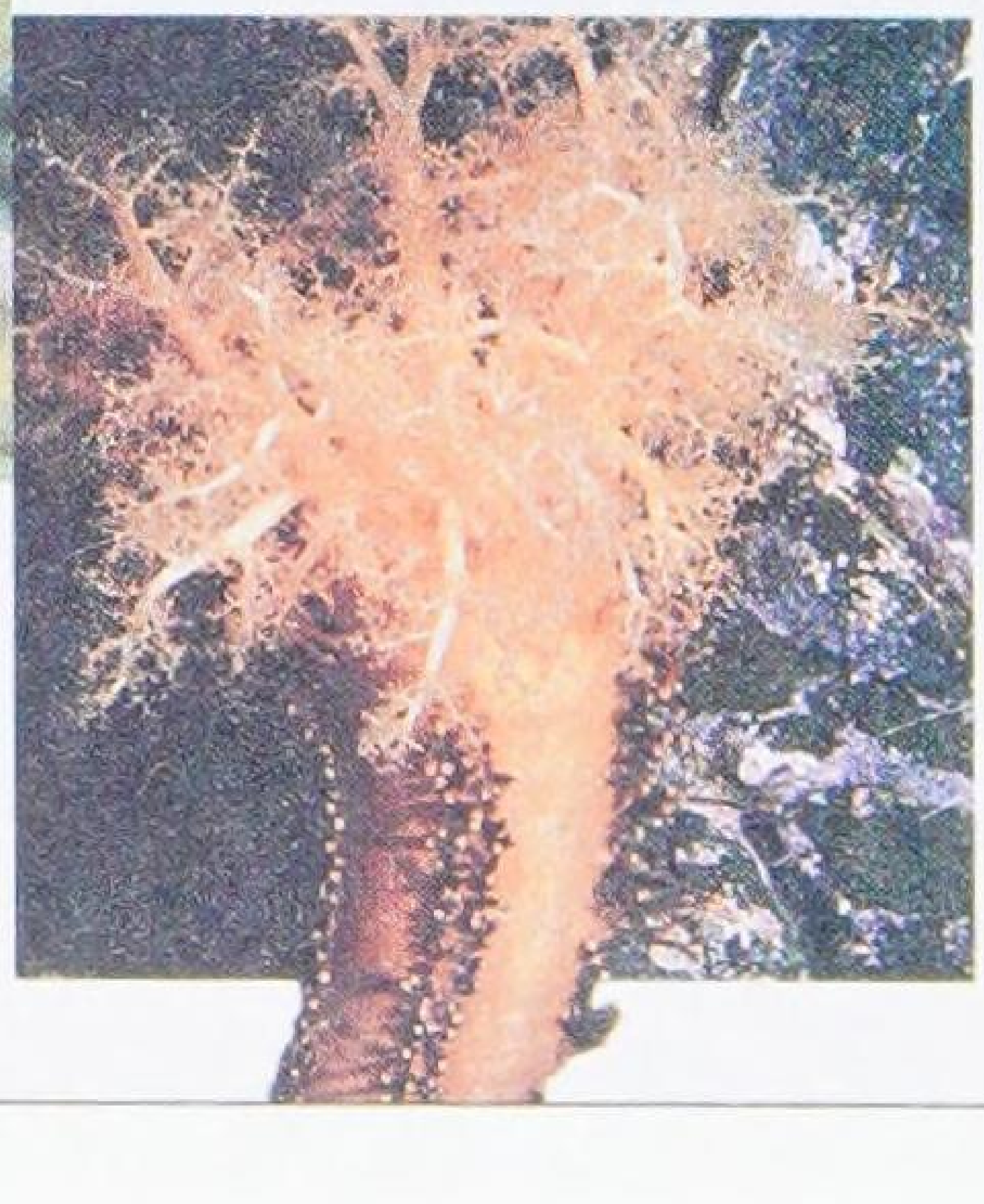
Brittle star



Sand dollar



Sea urchin



Sea cucumber

MINI-Lab

How do tube feet open clam shells?

Carry out this modeling activity to show how sea stars can open clam shells that are held closed by muscles. Hold your arm straight out, palm up. Place a heavy book on your hand. Have your partner time how long you can hold your arm up with the book on it. *Describe* how your arm feels after awhile. If the book represents the sea star and your arm represents the clam, *infer* how the sea star successfully overcomes the clam to obtain food.

Echinoderms are providing scientists with important information about how body parts regenerate. They are also important to the marine environment because they feed on dead organisms and help recycle materials. Many oyster and clam farmers don't find them as helpful. Sea stars feed on oysters and clams and destroy millions of dollars' worth of these organisms each year.

Scientists think that echinoderms are the most advanced group of invertebrates. They have radial symmetry like some of the less complex invertebrates, but they also have complex body systems. Another reason scientists view them as advanced is the way an echinoderm embryo develops. It develops the same way the embryos of chordates do, and not like the embryos of less complex invertebrates. Humans belong to the chordate phylum which you will study in the next chapter.

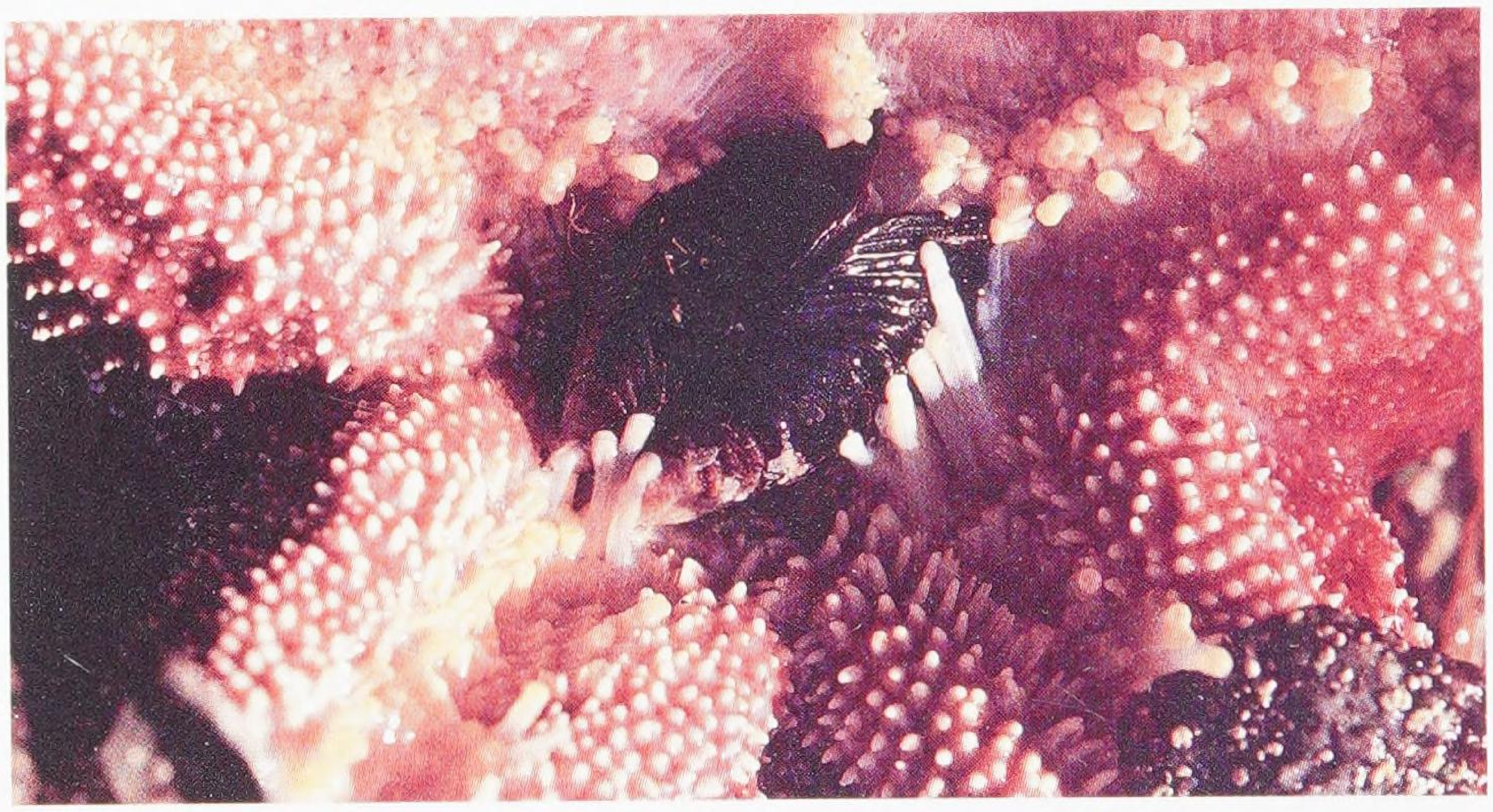


Figure 14-19. A sea star using its tube feet to open an oyster.

SECTION REVIEW

1. Why are echinoderms called spiny-skinned animals?
2. What features do all echinoderms have in common?
3. How do echinoderms move and get their food?
4. **Apply:** Why are sea stars common in coral reefs?
5. **Connect to Physics:** Sea stars that wash onto the beach cannot crawl back into the water. Why?

Skill Builder

Observing and Inferring

Observe the echinoderms pictured on page 343 and infer why they are slow moving and live on the ocean floor. If you need help, refer to Observing and Inferring in the **Skill Handbook** on page 682.

CHAPTER REVIEW

SUMMARY

14-1: Mollusks

1. Mollusks are soft-bodied invertebrates usually covered by a hard shell. Mollusks move by means of a muscular foot. A mollusk's body organs are located together in the visceral mass.

2. Mollusks with one shell, such as snails, are univalves. Bivalves are mollusks with two shells hinged together. Clams, and oysters are bivalves. Squid are cephalopods. A cephalopod has a foot divided into tentacles, and it has an internal shell.

14-2: Segmented Worms

1. Annelids are animals with segmented bodies. Annelids have a body cavity to hold internal organs. They have bristle-like structures called setae to help them move.

2. Earthworms have a digestive system made of a mouth, crop, gizzard, intestine, and anus. Earthworms burrow through soil, eating it as they go.

3. Both mollusks and annelid worms have a body cavity to hold body organs. They both develop from the same type of larva.

14-3: Arthropods

1. Arthropods are classified by number of body segments and appendages.

2. Arthropods are covered by an exoskeleton. The exoskeleton covers, protects, and supports the body.

3. Metamorphosis is a series of developmental stages. Complete metamorphosis has four stages: egg, larva, pupa, and adult. Incomplete metamorphosis has three stages: egg, nymph, and adult.

14-4: Science and Society: Pesticides

1. Pesticides control populations of insects that damage crops and ornamental plants. They allow farmers to produce greater amounts of crops.

2. Pesticides can build up in, and poison, animals that come in contact with them. Pesticides that are sprayed can be inhaled by humans. They can also accumulate in the soil and run off into water supplies and contaminate them.

14-5: Echinoderms

1. Echinoderms are spiny-skinned invertebrates. They all have a water-vascular system to help the animal move, feed, get oxygen, and get rid of wastes.

2. Sea stars use their tube feet to open the shells of mollusks. They push their stomach into the mollusk and use enzymes to digest the food.

KEY SCIENCE WORDS

a. **appendages**
b. **Arthropoda**
c. **closed circulatory system**
d. **crop**
e. **echinoderms**
f. **exoskeleton**
g. **gills**
h. **gizzard**
i. **mantle**
j. **metamorphosis**
k. **mollusks**
l. **molting**
m. **open circulatory system**
n. **pesticide**
o. **radula**
p. **setae**
q. **spiracles**
r. **tube feet**
s. **water-vascular system**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. temporary food storage site
2. tongue-like organ in univalves
3. bristles earthworms use to hold on to soil
4. structure in earthworms that grinds soil
5. arms, legs, and antennae
6. outer covering made of chitin
7. shedding of the exoskeleton
8. spiny-skinned invertebrates
9. openings for air in some arthropods
10. structure that secretes the shell of mollusks

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. The _______ hold(s) the organs of mollusks.
   a. gills c. mantle
   b. foot d. visceral mass
2. An example of an annelid is a(n) _______.
   a. snail c. octopus
   b. slug d. earthworm
3. The organism with a closed circulatory system is a(n) _______.
   a. earthworm c. oyster
   b. snail d. slug
4. The largest phylum of animals are the _______.
   a. arthropods c. annelids
   b. mollusks d. echinoderms
5. Organisms with two body regions are _______.
   a. insects c. arachnids
   b. mollusks d. annelids
6. An example of an arthropod is a(n) _______.
   a. snail c. slug
   b. earthworm d. scorpion
7. _______ are organisms with radial symmetry.
   a. Annelids c. Echinoderms
   b. Mollusks d. Arthropods
8. The structures echinoderms use to move and open shells are _______.
   a. calcium plates c. spines
   b. arms d. tube feet
9. Regeneration is a means of reproduction in _______.
   a. sea stars c. octopus
   b. snails d. slugs
10. The most DDT would be found in _______.
    a. soil c. a worm
    b. a bird d. water

USING LAB SKILLS

11. In the Mini-Lab on page 337, you observed metamorphosis of fruit flies. Obtain a larva of a moth or butterfly, an insect cage, and leaves for the larva to eat. Place the larva in the insect cage and observe it until it becomes a moth or butterfly. How is metamorphosis of a moth or butterfly different from fruit fly metamorphosis?
12. In the Mini-Lab on page 344, you modeled how some echinoderms open a clam. Wet a suction cup and press it against a variety of surfaces. Can you pick up objects by holding the suction cup? Compare this to tube feet.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Describe how each class of mollusks obtains food.
14. Compare the ability of clams, oysters, scallops, and squid to protect themselves.
15. Compare an earthworm gizzard with teeth.
16. What evidence do scientists have that mollusks and annelids share a common ancestor?

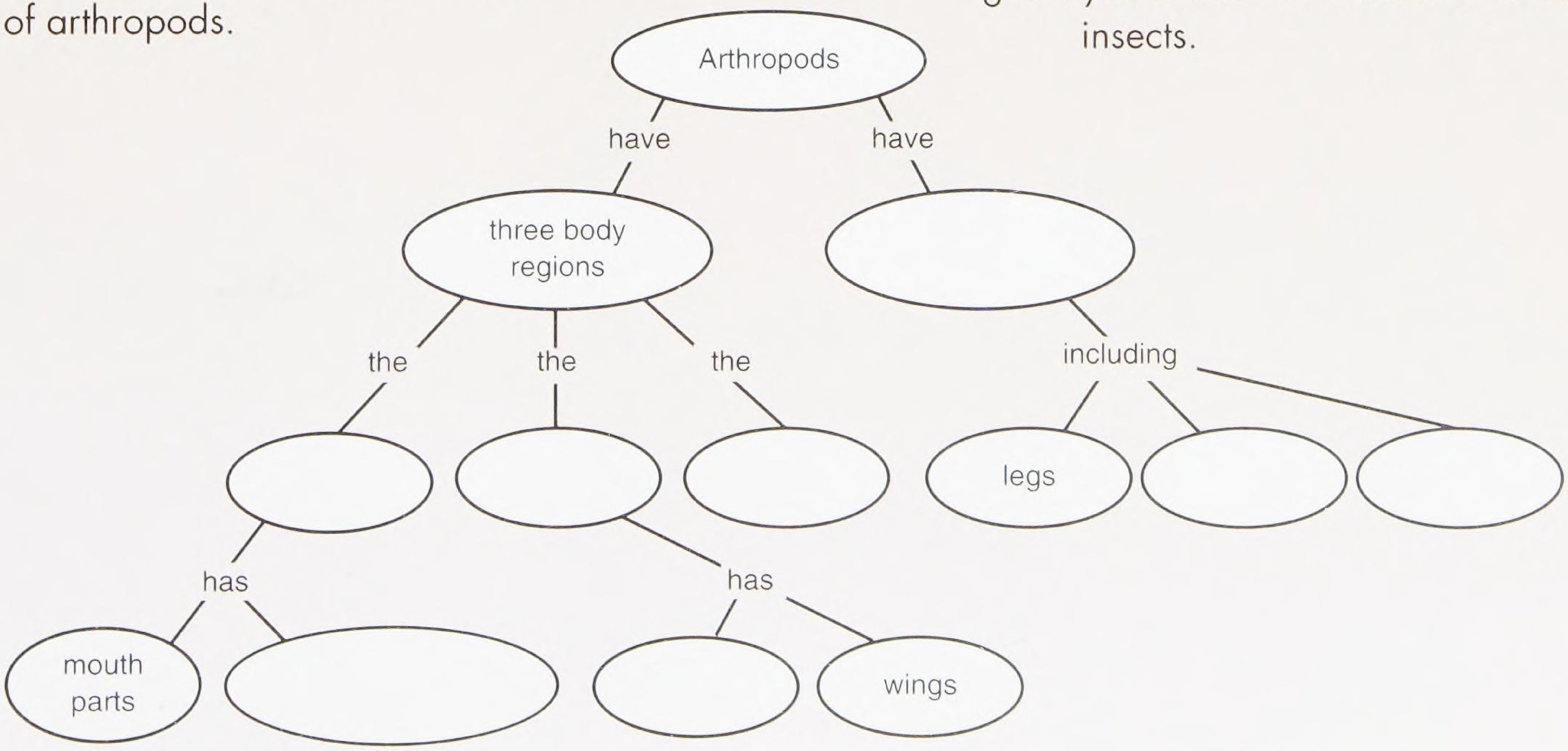
APPLY

17. Describe the adaptations of the spinnerets and swimmerets.
18. Why is it unwise to cut apart sea stars and throw the parts back into a water area which is already overpopulated with them?
19. What problems do arthropods have immediately after molting?
20. Based on your observations of the structure of a segmented worm in Activity 14-1, explain why you see many earthworms on the surface of the soil after a heavy rain.
21. What structures do insects have that enable them to pollinate flowers?

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Classifying:** Group the following animals into arthropod classes: spider, pill bug, crayfish, grasshopper, crab, silverfish, cricket, sow bug, tick, scorpion, shrimp, barnacle, butterfly.
2. **Concept Mapping:** Copy and complete the map below that describes the characteristics of arthropods.



3. **Observing and Inferring:** Of what advantage is it to barnacles to live on a whale?
4. **Classifying:** The suffix *-ptera* means wings. Find out the meaning of the prefix of each insect class and give an example of a member of each group.

DIPTERA
ORTHOPTERA
COLEOPTERA
HOMOPTERA
HEMIPTERA

5. **Making and Using Graphs:** Make a pie graph of the species of arthropods.

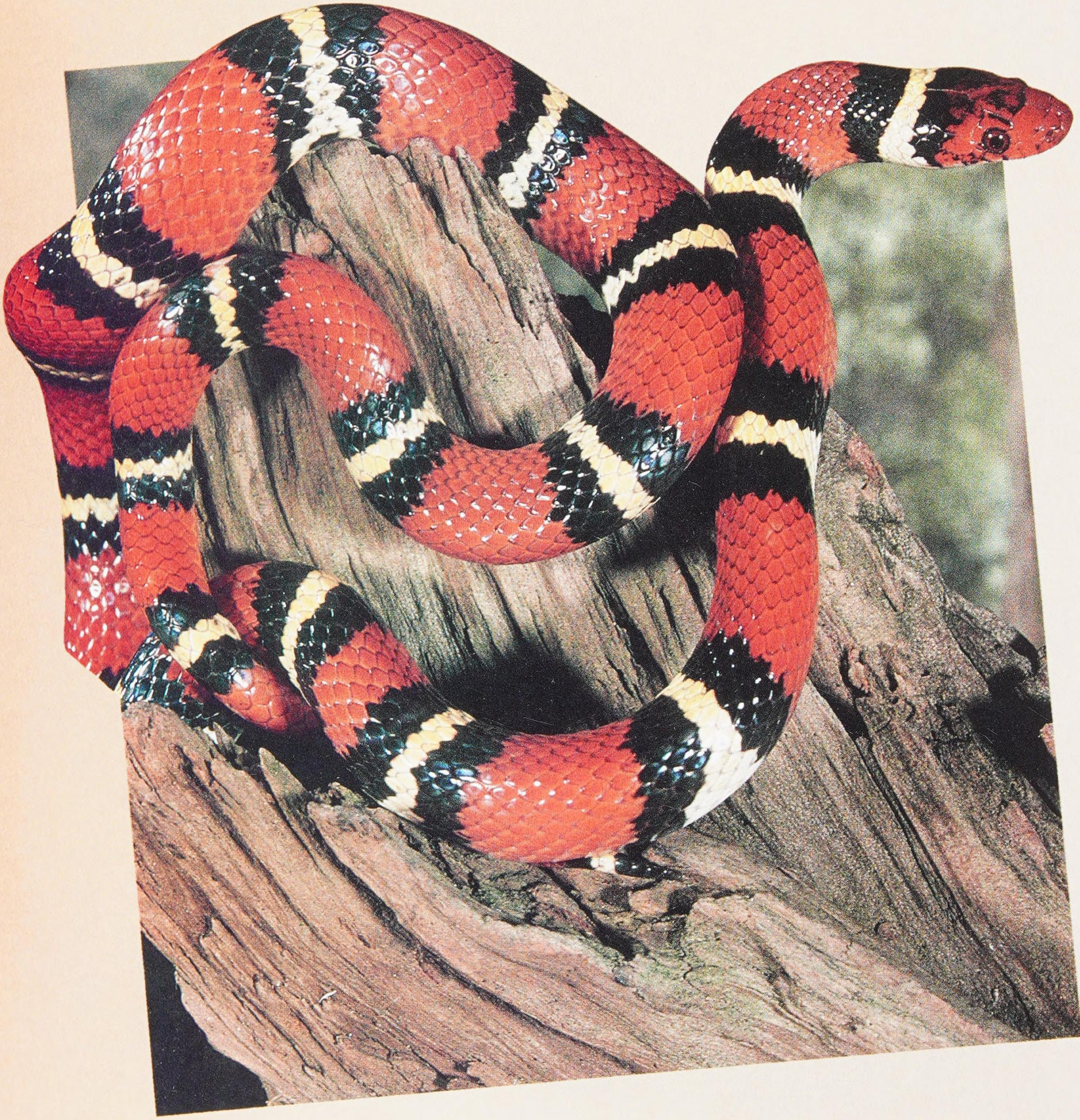
Class of Arthropod	# of species
Arachnids	100 000
Crustaceans	25 000
Insects (known)	700 000

PROJECTS

1. Find out about the dance bees use to communicate to each other. Explain and diagram the dance to your class.
2. Begin an insect collection of your own. There are many good books at your local library to guide you in how to collect and identify insects.

CHAPTER

15 Cold-Blooded Vertebrates

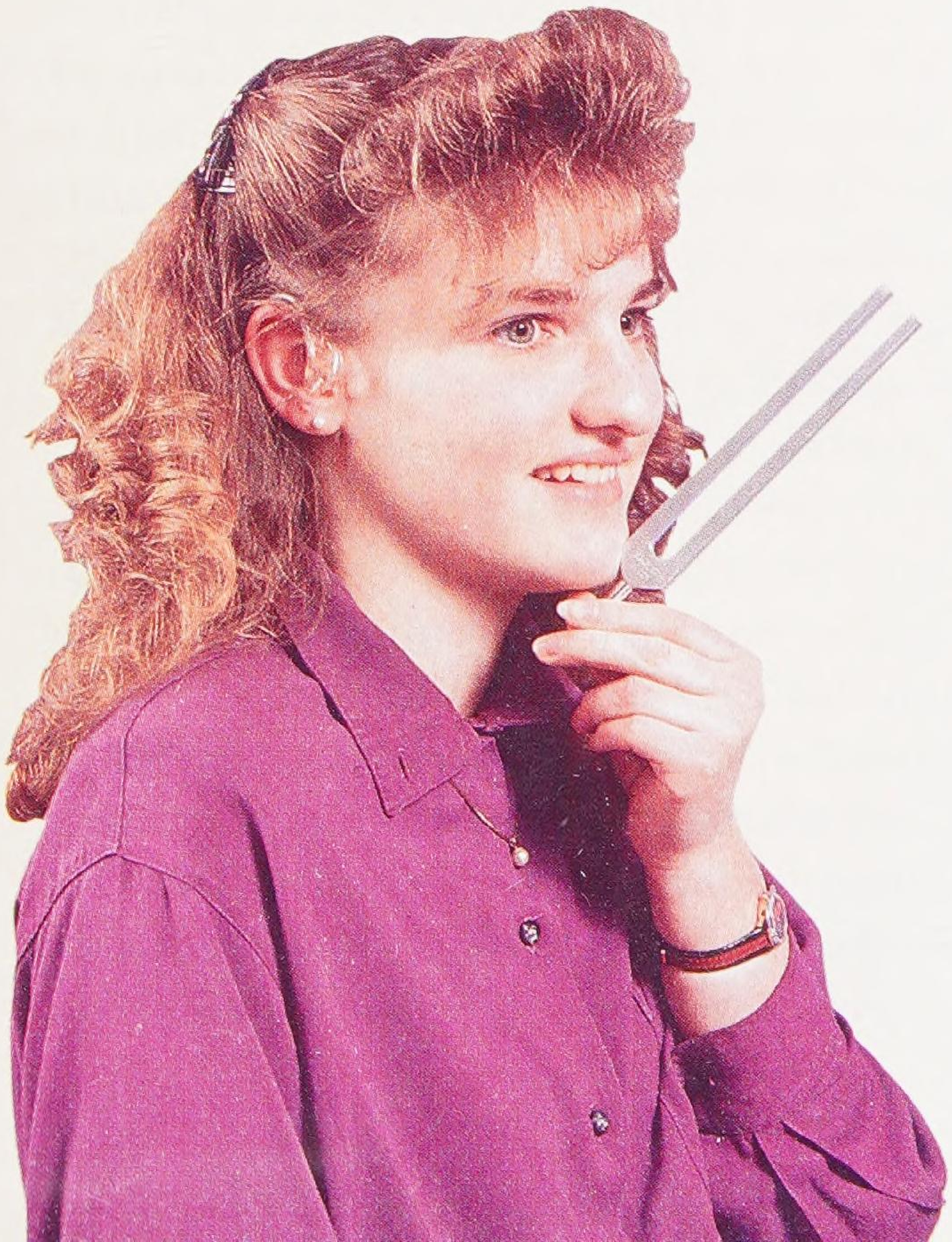


Exactly how much do you know about reptiles? For example, do snakes sting with their tongues? How can a snake swallow something as big as a deer? And, if snakes have no ears, how do they hear?

FIND OUT!

Do this simple activity.

Hold a tuning fork by the stem and tap it on a hard piece of rubber. Then hold it next to your ear. What happens? Now tap it again and this time, press the base of the stem hard against your chin. What do you observe? Snakes receive similar vibrations from the environment. How do you think a snake detects vibrations? *Predict* how different animals make use of vibrations.



Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 15-1 Fish
- Vertebrate Characteristics
- What Is a Fish?
- Jawless Fish
- Cartilaginous Fish
- Bony Fish

Section 15-2 Amphibians
- What Is an Amphibian?
- Origin of Amphibians
- Frogs, Toads, and Salamanders

Section 15-3 Science and Society Amphibian Population Decline
- Where Have All the Frogs Gone?

Section 15-4 Reptiles
- What Is a Reptile?
- Origin of Reptiles
- Modern Reptiles

Previewing Science Skills

- In the **Skill Builders,** you will outline, sequence, and make a concept map.
- In the **Activities,** you will hypothesize, observe, collect data, measure, and experiment.
- In the **MINI-Labs,** you will compare and observe.

What's next?

In this chapter, you will learn about cold-blooded vertebrates. First you will learn about fish and amphibians. Then you will study about reptiles, what they are and how they live.

15-1 Fish

New Science Words

chordates
notochord
dorsal nerve cord
gill slits
endoskeleton
cold-blooded
warm-blooded
fish
fins
scales
cartilage
predator
prey

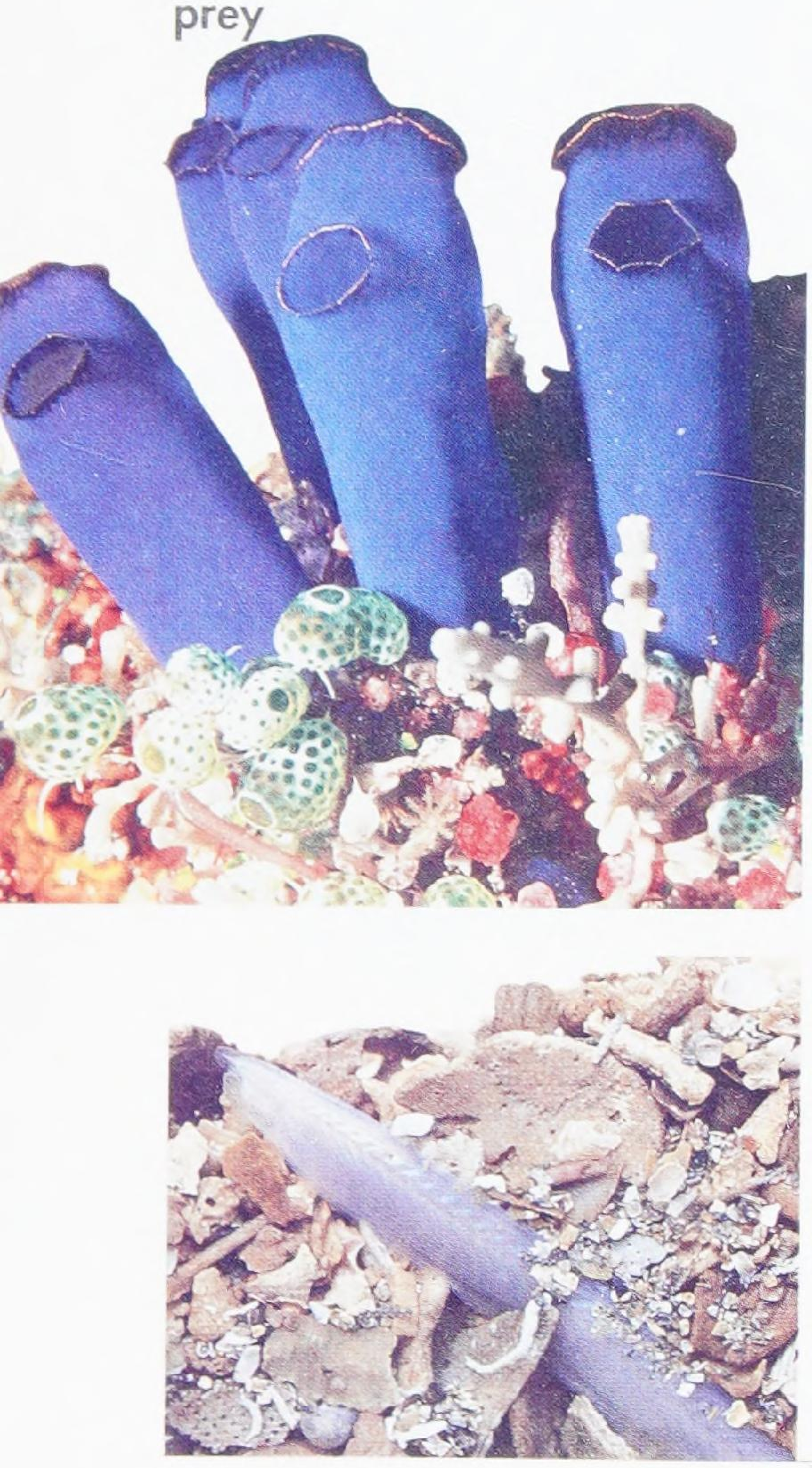


Figure 15-1. Tunicates, top, and lancelets, bottom, are both chordates.

Objectives

- Identify the major characteristics of chordates.
- Explain the differences between cold-blooded animals and warm-blooded animals.
- Describe the characteristics that identify the three classes of fish.

Vertebrate Characteristics

Most of the groups of animals you've studied so far live in water. They are all invertebrates, and their bodies are well adapted to aquatic life. Animals with backbones, the vertebrates, can be found in almost every environment—oceans, fresh water, land, and air. How are these organisms adapted to all these types of environments? To answer that question, let's look at some of the traits of vertebrates.

Vertebrate animals belong to the phylum Chordata (kor DAHT uh). The chordates are grouped into three subphyla, the largest being the vertebrates. The two small subphyla are made up of tunicates and lancelets, pictured in Figure 15-1. Tunicates, also called sea squirts, are sessile. They live a life very much like that of a clam or sponge. They are filter-feeders and live attached to objects in the sea. Lancelets also live in salt water and look a lot like fish. They can swim freely, but spend most of their time buried in the sand with only their heads sticking out. Lancelets are also filter-feeders.

What do sea squirts and lancelets have in common with vertebrates such as whales, bears, fish, and humans? Actually, three things: at sometime during their lives all **chordates** have a notochord, a dorsal hollow nerve cord, and gill slits. The **notochord** is a flexible, rodlike structure along the dorsal side, or back, of an animal. In vertebrates, the notochord is eventually replaced by bones that make up a backbone in the adult. A **dorsal nerve cord** is a bundle of nerves that lies above the notochord. In most vertebrates, it develops into a spinal cord with a brain at the front end. **Gill slits** are paired openings located in the throat behind the mouth. Gill slits develop into gills in fish. Traces of gills can be seen in human embryos.

Vertebrates are named for the column of bones called vertebrae that encloses the dorsal nerve cord. The vertebrae, skull, and the rest of the internal skeleton is called the **endoskeleton.** *Endo-* means "within." An endoskeleton supports and protects internal organs and is the place where muscles are attached.

There are seven classes of vertebrates. Members of five of the seven classes of vertebrates are cold-blooded. The body temperature of a **cold-blooded** animal changes with the temperature around it. **Warm-blooded** animals such as birds and mammals have a body temperature that stays the same in any environment. You are warm-blooded. In this chapter, you will study cold-blooded vertebrates—fish, amphibians, and reptiles.

Connect to...

Physics

In a fluid, forces are transmitted equally in every direction. Some organisms have hydrostatic skeletons, fluid-filled bodies that support body shape and organs. Which organisms you have studied thus far do you think have hydrostatic skeletons?

What Is a Fish?

When you hear the word *fish,* the first thing that probably comes to mind is a pet goldfish, or a can of tuna in the kitchen cabinet. Actually, there are more than 30 000 different species of fish—more than all other species of vertebrates. What is a fish, and how is it adapted to its environment?

Fish are cold-blooded vertebrates that have three adaptations that allow them to live in water. These adaptations are gills, fins, and scales. All fish have gills for breathing. Located in the throat area, gills are structures that take oxygen from water as it passes over them. At the same time, carbon dioxide is given off to the water surrounding the gills. Second, most fish have **fins,** fanlike structures used for steering, balancing, and moving. The large tail fin moves back and forth to propel the fish through the water. Third, most fish have **scales,** hard, thin, overlapping plates that cover and protect a fish's body. Each scale grows larger as the fish grows. You can see the yearly growth rings in Figure 15-2. Like the age of some trees, the age of some fish is estimated by counting growth rings.

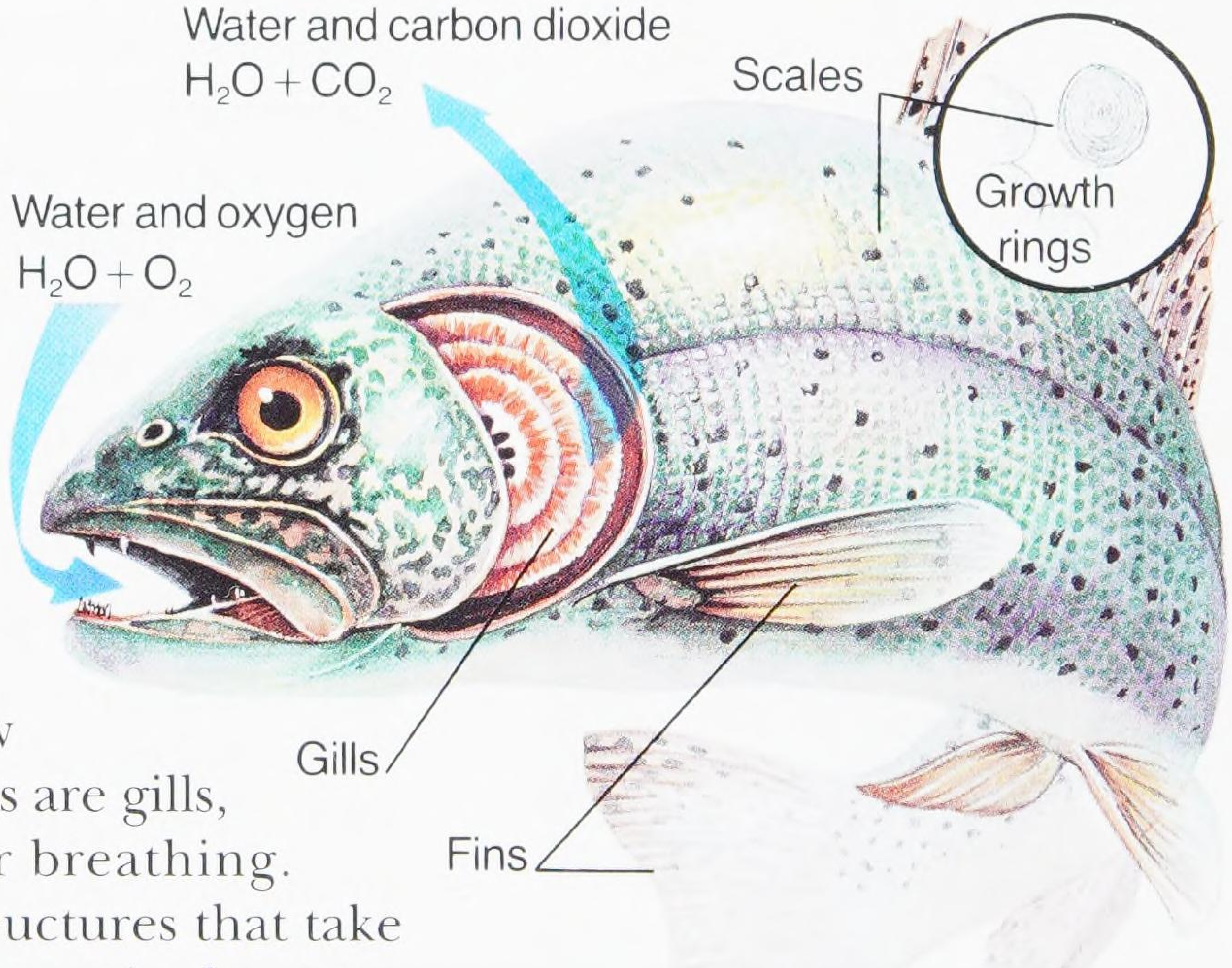


Figure 15-2. Fish have gills for taking in oxygen and scales for protection. Fins are used for steering, balancing, and moving.

Fish are grouped into three classes, jawless fish, cartilaginous (kart uhl AJ uh nuhs) fish, and bony fish.

Jawless Fish

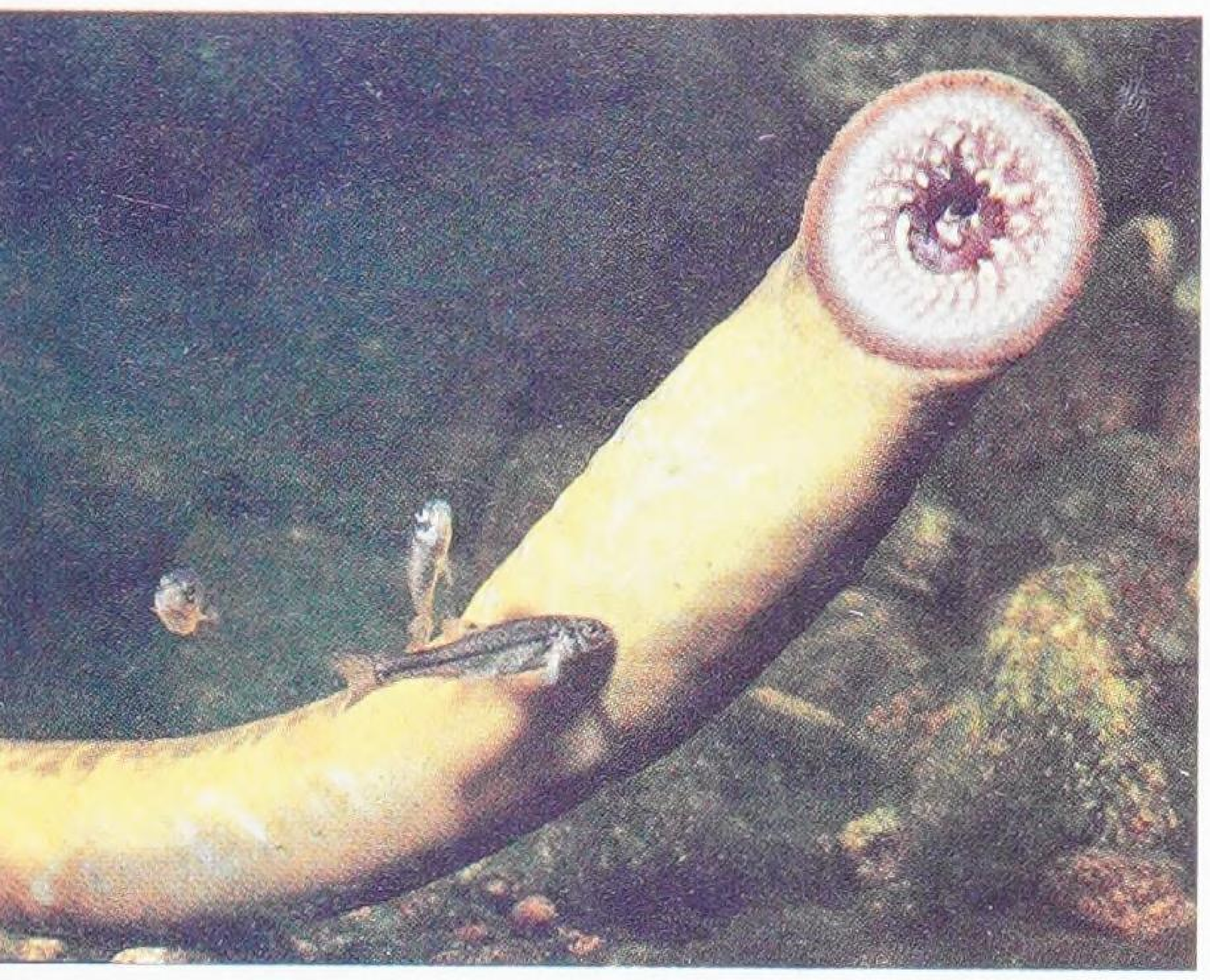


Figure 15-3. Lampreys are jawless fish that feed on the blood and body fluids of other fish.

The lamprey in Figure 15-3 belongs to the class Agnatha. *Agnatha* is a Greek word that means "jawless." These jawless fish have round mouths and long tubelike bodies covered with slimy skin with no scales. Fish in this class have very flexible bodies made of cartilage. **Cartilage** is a tough, flexible tissue that is not as hard as bone. Feel your ears and the tip of your nose. These are also made of cartilage.

Hagfish live only in salt water, but many lampreys live in fresh water. Lampreys use their round mouths to attach to other fish by suction. They cut into the fish with toothlike structures and feed on its blood and body fluids. You can see the mouth of a lamprey in Figure 15-3.

Cartilaginous Fish

Sharks, skates, and rays are members of the class Chondrichthyes (kahn DRIHK thee eez). They have skeletons made of cartilage like jawless fish. Unlike jawless fish however, chondrichthyes have movable jaws and scales. The scales resemble vertebrate teeth and cause their skin to feel like fine sandpaper.

The fact that sharks are predators gives them a reputation for being killers. A **predator** is an organism that kills and eats another for food. The organism that is killed and eaten is the **prey.** Unless they are provoked, few sharks will attack humans.

Shark eggs are fertilized inside the female's body. In most species, the fertilized eggs develop in the body and young are born alive.

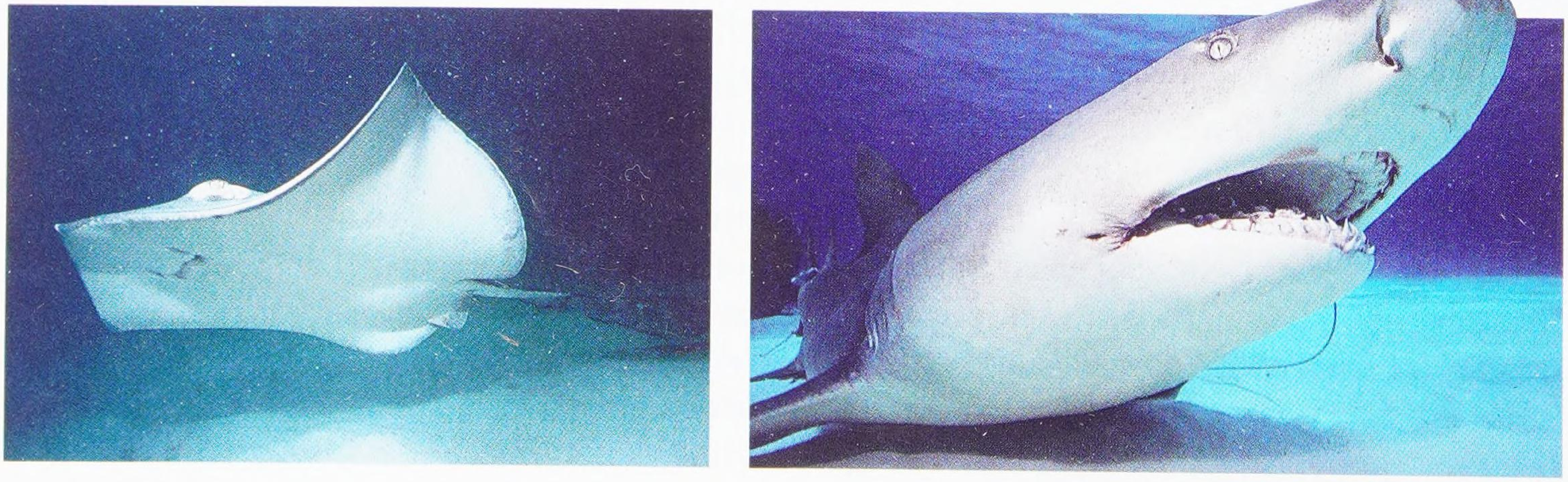


Figure 15-4. Rays (left) and sharks (right) are members of the class Chondrichthyes.

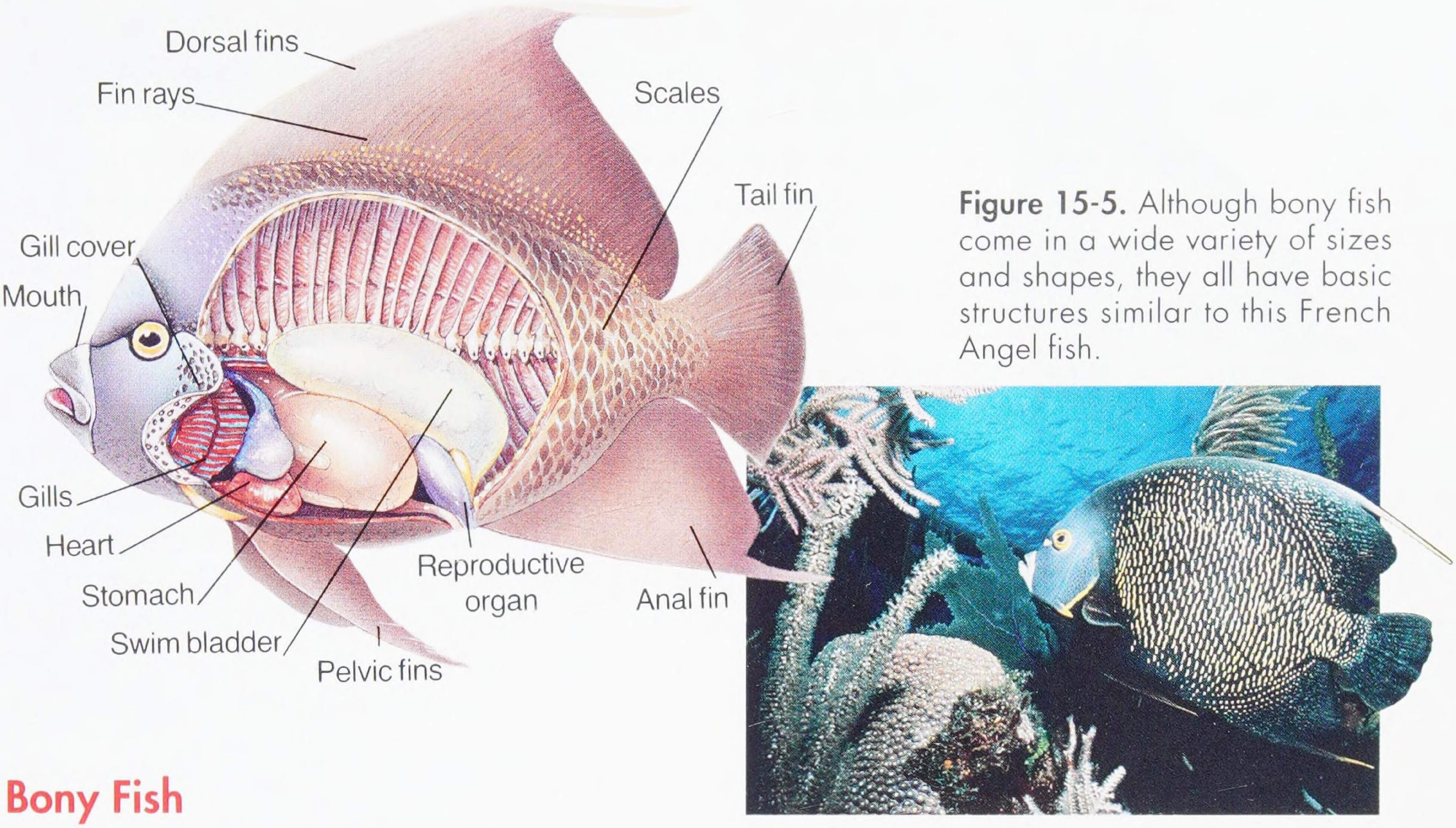


Figure 15-5. Although bony fish come in a wide variety of sizes and shapes, they all have basic structures similar to this French Angel fish.

Bony Fish

Bony fish make up the class Osteichthyes (ahs tee IHK thee eez). The word *osteon* is Greek for bone, and *ichthyes* is Greek for fish. Fish that belong to this class have skeletons made of bone. About 95 percent of all species of fish belong to this class.

Floating is an important adaptation for fish. Most bony fish have adaptations for floating. Some float by trapping gases in a balloonlike structure called the swim bladder. By adjusting the amount of gas in the swim bladder, fish can stay at a particular depth in the water with little effort. Find the swim bladder in Figure 15-5.

The body structure of bony fish, a French angel fish, is shown in Figure 15-5. The gills are covered and protected by a bony flap called the gill cover. Gill covers aid the fish in breathing. They open and close, moving the water taken in through the mouth over the gills.

Most kinds of bony fish have separate males and females. The females release large numbers of eggs into the water in a behavior called spawning. Males then swim over the eggs and release sperm. The joining of egg and sperm cells outside the female body is called external fertilization.

Scientists who specialize in studying fish have organized bony fish into three groups: lobe-finned fish, lungfish, and ray-finned fish. Most fish are ray-finned fish.

MINI-Lab

How does a fish adjust to depths?

Fill a balloon with air. Place it in a bowl of water. What happens? What structure in a fish does the balloon model? *Compare* where in the water (surface, deep) a fish would be as this structure is being filled with air.

Figure 15-6. Fish are food for many animals, including this Puffin.

Science and READING

Imagine you have just opened a fish market in your hometown. What different species will you offer, where will you get them, and what facts do you need to know about them?

Ray-finned fish have fins made of long, thin bones covered with skin. Yellow perch, tuna, salmon, swordfish, and eels are all ray-finned fish.

Lungfish have both gills and lungs for breathing. This adaptation allows many to live in shallow waters that dry up in summer. When the water evaporates, lungfish burrow into the mud and cover themselves with mucus until water returns. Lungfish have been found along the coast of South America, Australia, and Africa.

Lobe-finned fish have fins that are lobe-like and fleshy. It was thought that these organisms had been extinct for more than 70 million years. But in 1938, one was caught in a net by some South African fishermen. Several living lobe-finned fish have been studied since. Scientists observed these fish using their lobed fins to swim in a way similar to the way land vertebrates walk. Lobe-finned fish are important because scientists think these fish are the ancestors of the first land vertebrates.

Fish are an important food source for animals such as raccoons, bears, and sea birds. They are also an important food source for humans. Some researchers hypothesize fish oils protect blood vessels from fat deposits that lead to heart disease. Because fish feed on insect larvae such as those of mosquitoes, they help to control insect populations that are pesty or dangerous. Some species of fish feed on plants that clog waterways. This helps keep them clear for boat traffic.

SECTION REVIEW

1. What are three characteristics of chordates?
2. What is the function of the endoskeleton in vertebrates?
3. Explain the differences between cold-blooded animals and warm-blooded animals.
4. What are the characteristics of the three fish classes?
5. **Apply:** Female fish lay thousands of eggs. Why are the waters not overcrowded with fish?
6. **Connect to Physics:** Suggest a reason why bottom-dwelling fish usually don't have swim bladders.

Skill Builder

Outlining

Outline the characteristics of chordates, vertebrates, and fish. If you need help, refer to Outlining in the **Skill Handbook** on page 681.

DESIGNING AN EXPERIMENT

ACTIVITY 15–1

Does Water Temperature Affect Fish?

You remember from Chapter 1 that organisms adjust to changes in their environment. The ability of an organism to maintain steady conditions no matter what is going on inside or outside the organism is homeostasis. Water temperature in a pond or river changes very slowly. However, sometimes warmer water is dumped into bodies of water in which fish live. In this experiment, you will be the scientist and determine what happens to a fish if the water in which it lives warms up or cools down.

Getting Started

In preparation for designing your experiment, answer the following questions:

1. What question are you investigating?
2. How does a fish take in oxygen and give off carbon dioxide?
3. What kind of water has more dissolved oxygen in it, warm or cold?

Safety Notes

Use extreme care when handling live animals. Wash your hands after the experiment.

Hypothesis

What is your **hypothesis**? What is the reasoning behind your hypothesis? Share this information with your group and decide on a group hypothesis.

Brainstorm

As a group, make a list of ways to test your hypothesis.

Experimental Plan

- **Design an experiment** to test one variable.
- Make a numbered set of directions, similar to a recipe, that anyone could follow to do the experiment. What will your data table include for collecting quantitative data?
- Make a list of materials and the quantities you need for the experiment.

Answer the following questions

1. What will be your control?
2. What will be the variable?
3. What will you measure?
4. How many fish will you test?
5. How many trials will you use?
6. Have you made a data table?

Make sure your teacher has approved your experimental plan before you go futher.

Data and Observations

1. Make a table of your data.
2. Make a graph of your data.

Data Analysis and Interpretation

1. How does water temperature affect fish?
2. What is the rate at which a fish moves water across its gills directly related to?
3. Was your **hypothesis** supported by your data? Explain.
4. If your **hypothesis** was not supported, what can you conclude?
5. How does this lab *relate* to what you are studying in class?
6. Make a brief conclusion based on your data.
7. Could your results be used to determine the kind of environment in which fish can live?

Going Further

Design another experiment to test a second variable that you may have thought of.

15-2 Amphibians

New Science Words

amphibians
hibernation
estivation

Objectives

- Describe the adaptations that amphibians have for living in water and living on land.
- Identify the three kinds of amphibians and describe the characteristics of each.
- Describe the metamorphosis of a frog.

What Is an Amphibian?

The word *amphibian* comes from the Greek word *amphibios*, which means "double life." They are well named for **amphibians** are cold-blooded vertebrates that spend part of their life in water and part on land. Frogs, toads, and salamanders are amphibians. What adaptations do these animals have that allow them to live both on land and in water? Amphibians have moist, smooth, thin skin without scales. They can breathe through their skin. Oxygen and carbon dioxide are exchanged through the skin and the lining of the mouth. Amphibians also have very small, simple, saclike lungs in the chest cavity to use for breathing.

Because amphibians are cold-blooded, their body temperatures change when the temperature of their surroundings changes. Did you ever wonder how frogs and toads survive cold winters in the northern states? Amphibians have adaptations that protect them from very cold and very warm temperatures. During the cold winter months they become inactive. They bury themselves in mud or leaves until the temperature warms up. The period of inactivity in the winter is called **hibernation.** Inactivity during the hot, dry summer months is called **estivation.**

Another adaptation amphibians have to life on land is a strong skeleton. Organisms living in water are supported by the water. However, on land a stronger structure is needed to support the body.

Because their eggs lack shells and must be kept moist, most species of amphibians return to water to lay their eggs. The eggs hatch into larvae that live in water until they become adults and move to land.

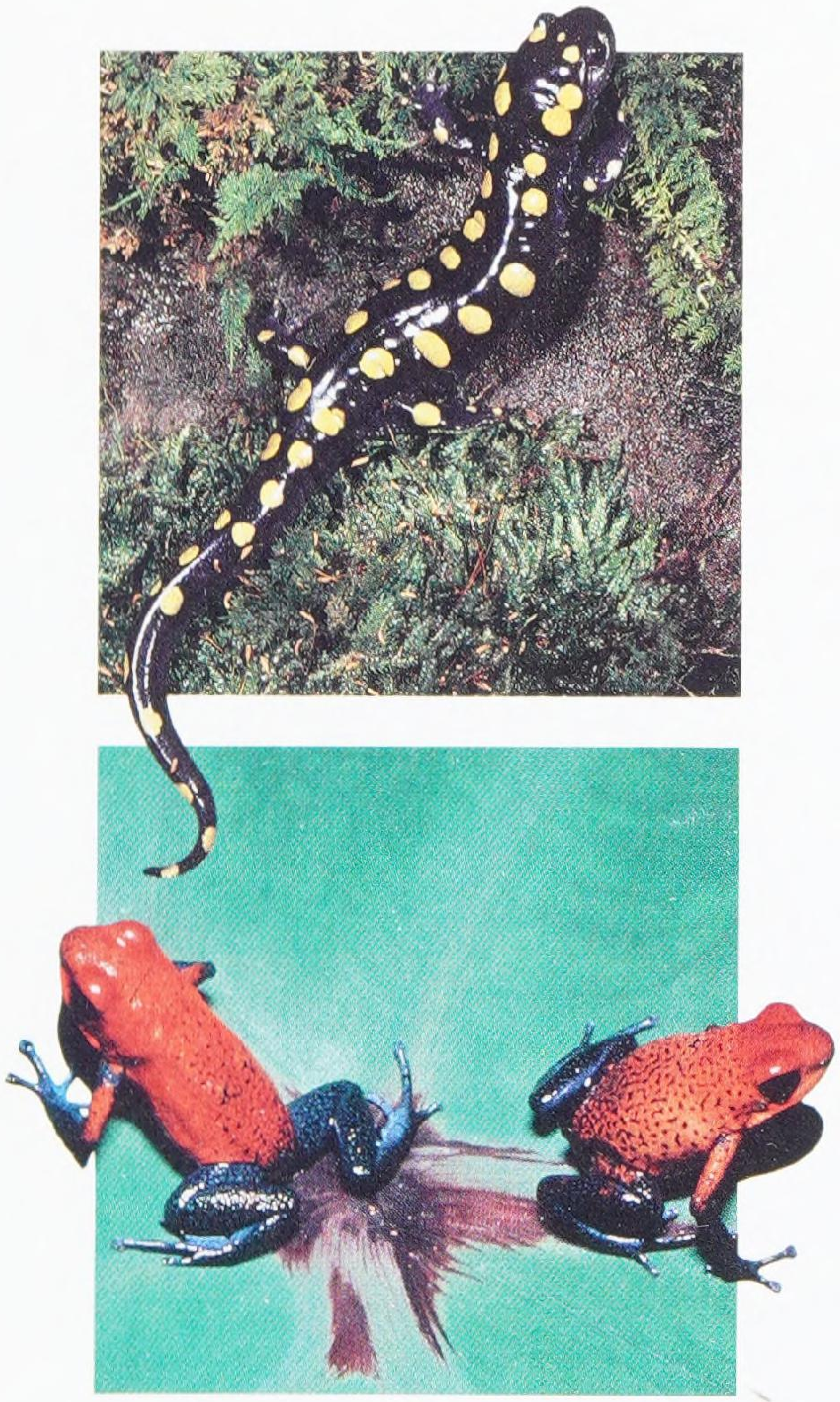


Figure 15-7. Salamanders, top, and frogs, bottom, are both types of amphibians.

Origin of Amphibians

The fossil record shows that fish were the first vertebrates on Earth. For about 150 million years they were the only vertebrates. Then as competition for food and space increased, the lobe-finned fish may have easily traveled across land searching for deeper water. The lobe-finned fish had lungs and bony fins that could have supported their weight on land. Amphibians are thought to have evolved from the lobe-finned fish about 350 million years ago.

Evolution favored the development of amphibians because there wasn't much competition on land. Almost free of predators, land provided a great supply of food in the form of insects, spiders, and other invertebrates. Amphibians were able to reproduce in large numbers, and many new species evolved. For 100 million years or more, amphibians were the dominant land animals.

Connect to... Earth Science

For organisms adapted to life in water, why is land a hostile environment?

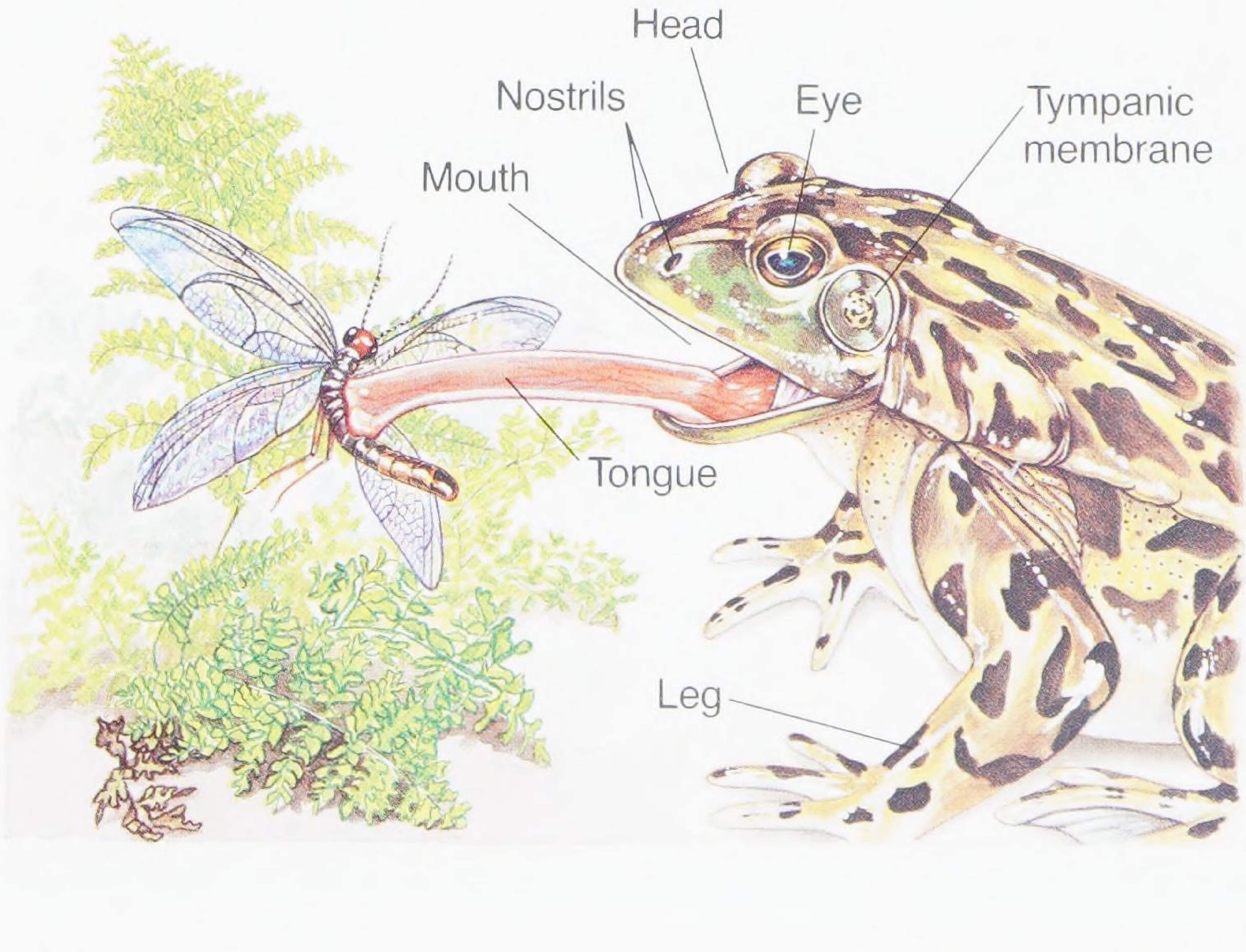
Frogs, Toads, and Salamanders

Frogs and toads are amphibians that have short, broad bodies with no neck, no tail, and four legs. The strong hind legs are longer than the front and are used for swimming and jumping. Bulging eyes and nostrils on top of the head let them see and breathe while almost totally submerged in water. On spring nights, they make their presence known with loud, distinctive sounds.

Figure 15-8 shows the external body structures of a frog. A frog's tongue is attached to the front of its mouth. When a frog sees an insect, it flips the loose end of its tongue out and the insect gets stuck in the sticky saliva on the tongue. Then the frog flips its catch back into its mouth. For hearing, frogs have round membranes called tympanic membranes on each side of the head just behind the eyes.

Toads live in drier environments than frogs. They have thick, rough skin that keeps them from drying out. Both frogs and toads return to the water to lay eggs.

Figure 15-8. The external body structures of a frog.



Recall that metamorphosis is a series of changes that a larva goes through to become an adult. Most frogs and toads have a two-stage life cycle, a larva that lives in water and an adult that lives on land. Figure 15-9 shows the metamorphosis of a leopard frog.

The rate at which amphibians grow and the length of time they spend as larvae depend on the species, the water temperature, and available food. The less food and the cooler the temperature, the longer it takes for metamorphosis. Bullfrogs may not go through metamorphosis for a year or more after hatching, whereas spadefoot toads change into adults in about two weeks.

Salamanders are amphibians often mistaken for lizards because of their long, slender bodies. They have smooth, moist skin and short legs. They rest under dead leaves and rocks during the day to avoid the drying heat of the sun. At night they come out and use their well-developed senses of smell and vision to feed on worms, crustaceans, and insects.

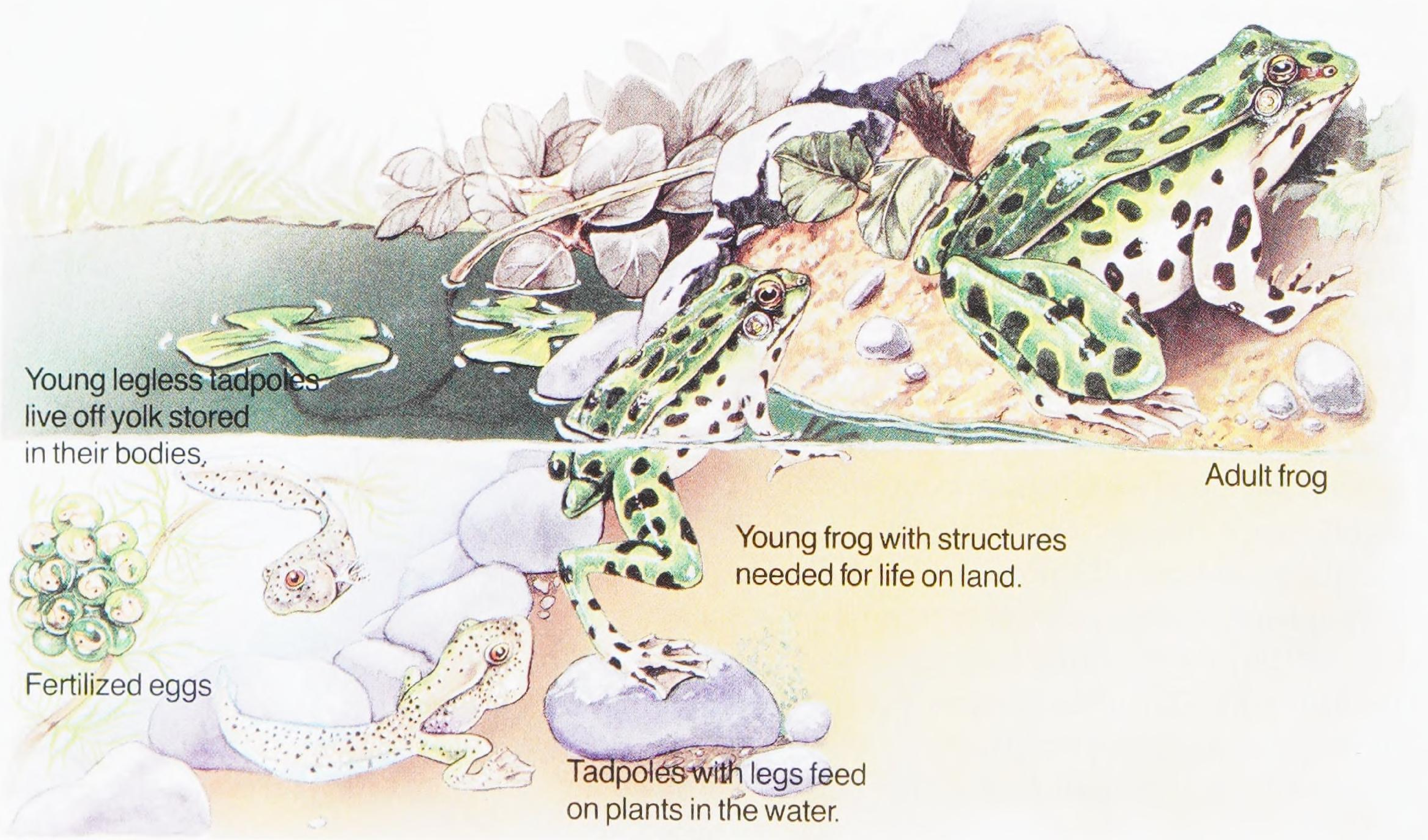
Amphibians are unique animals in many ways. Their adaptations allow them to live very successfully both on land and in water. The complete transition to life on land did not occur until the reptiles appeared. You will learn about reptiles in the next section.

MINI-Lab

How do frogs behave?

Obtain a live frog in a large empty jar. Carefully *observe* the frog. Notice the position of its legs as it sits. Observe the position of its mouth, eyes, nostrils, and ears. Observe the color of its dorsal and ventral sides. Return the frog to your teacher to place in the aquarium. Observe how the frog swims. **In your Journal,** describe the adaptations the frog has for living in water. What adaptations does it have for living on land?

Figure 15-9. Frogs undergo a series of changes from egg to adult.


Young legless tadpoles live off yolk stored in their bodies.
Adult frog
Young frog with structures needed for life on land.
Fertilized eggs
Tadpoles with legs feed on plants in the water.

PROBLEM SOLVING

Marsupial Frogs

Most frogs deposit their eggs in water where the eggs hatch into fishlike tadpoles. The tadpoles exchange gases and get nutrients in the water environment. Over a period of time, the tadpoles develop into adult frogs.

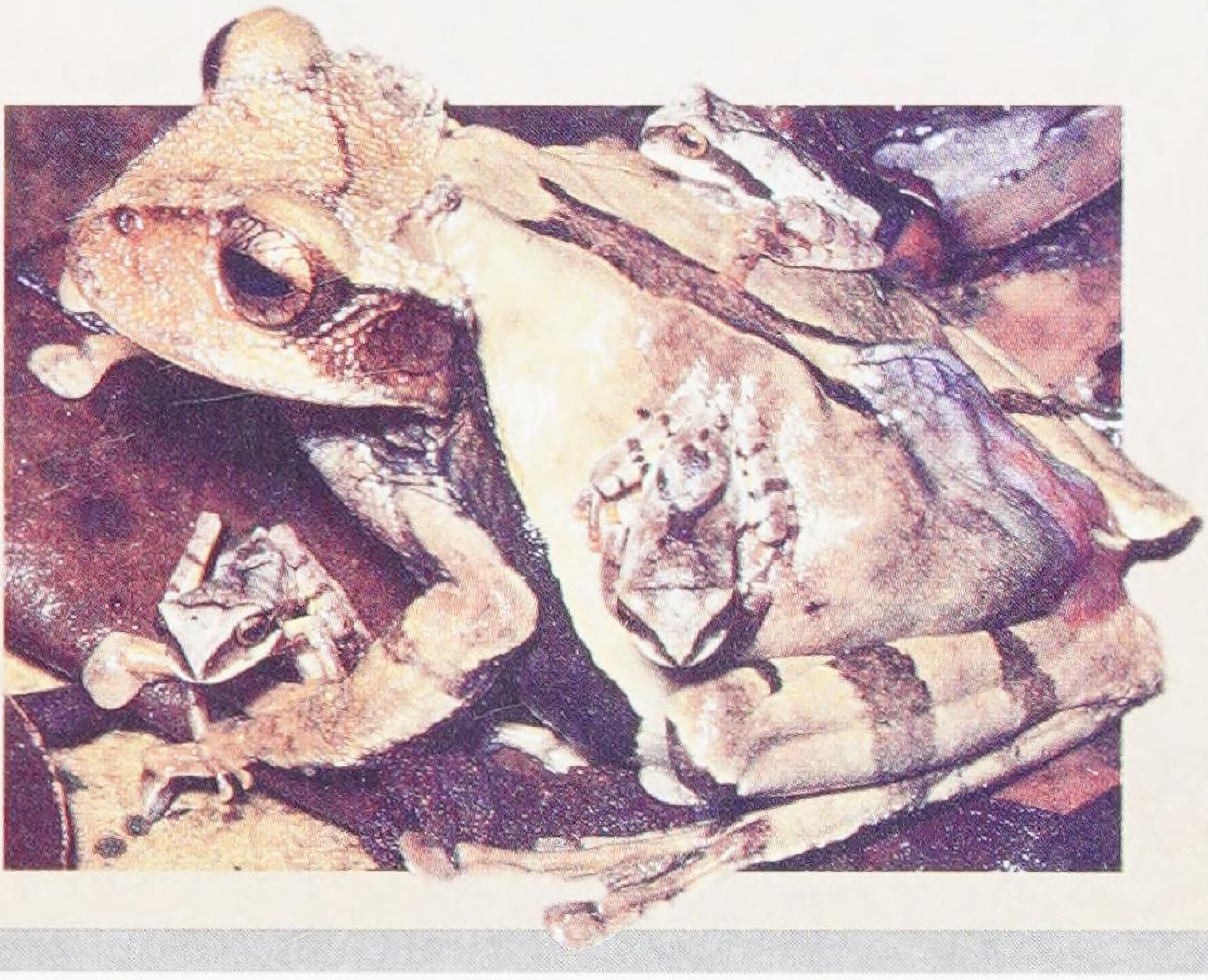
Researchers studying tree frogs in tropical rain forests have found that some species reproduce using a special pouch. Because of the pouch, they call these marsupial frogs.

The female marsupial frog lays eggs, and the male frog maneuvers the eggs one-by-one into a pouch on her back. The eggs are fertilized by sperm the male frog has deposited on the female's back.

The eggs are enclosed in a fluid-filled pouch lined with many blood vessels. In the pouch, the eggs undergo metamorphosis. The researchers think the tadpoles exchange gases, fluids, nutrients, and wastes with the female but get most of the nutrients they need from the yolk of the egg.

After development is complete, the female uses her toes to open the pouch and release the small frogs.

Think Critically: How is reproduction in marsupial frogs similar to that of other amphibians? How is it different?



SECTION REVIEW

1. List three characteristics of amphibians for living in water and three characteristics for living on land.
2. Describe the three kinds of amphibians.
3. Describe how a tadpole is different from a frog.
4. **Apply:** How would you explain the appearance of frogs and toads after a rain?
5. **Connect to Earth Science:** Find out some advantages to life on land.

Sequencing

Skill Builder

Sequence and describe each stage of frog metamorphosis. If you need help, refer to Sequencing in the **Skill Handbook** on page 680.

SCIENCE & SOCIETY

15-3 Amphibian Population Decline

New Science Words

biological indicators

Objectives

- State three possible reasons for the recent decline in amphibian populations.
- Explain why amphibians are likely to be affected by pollution.

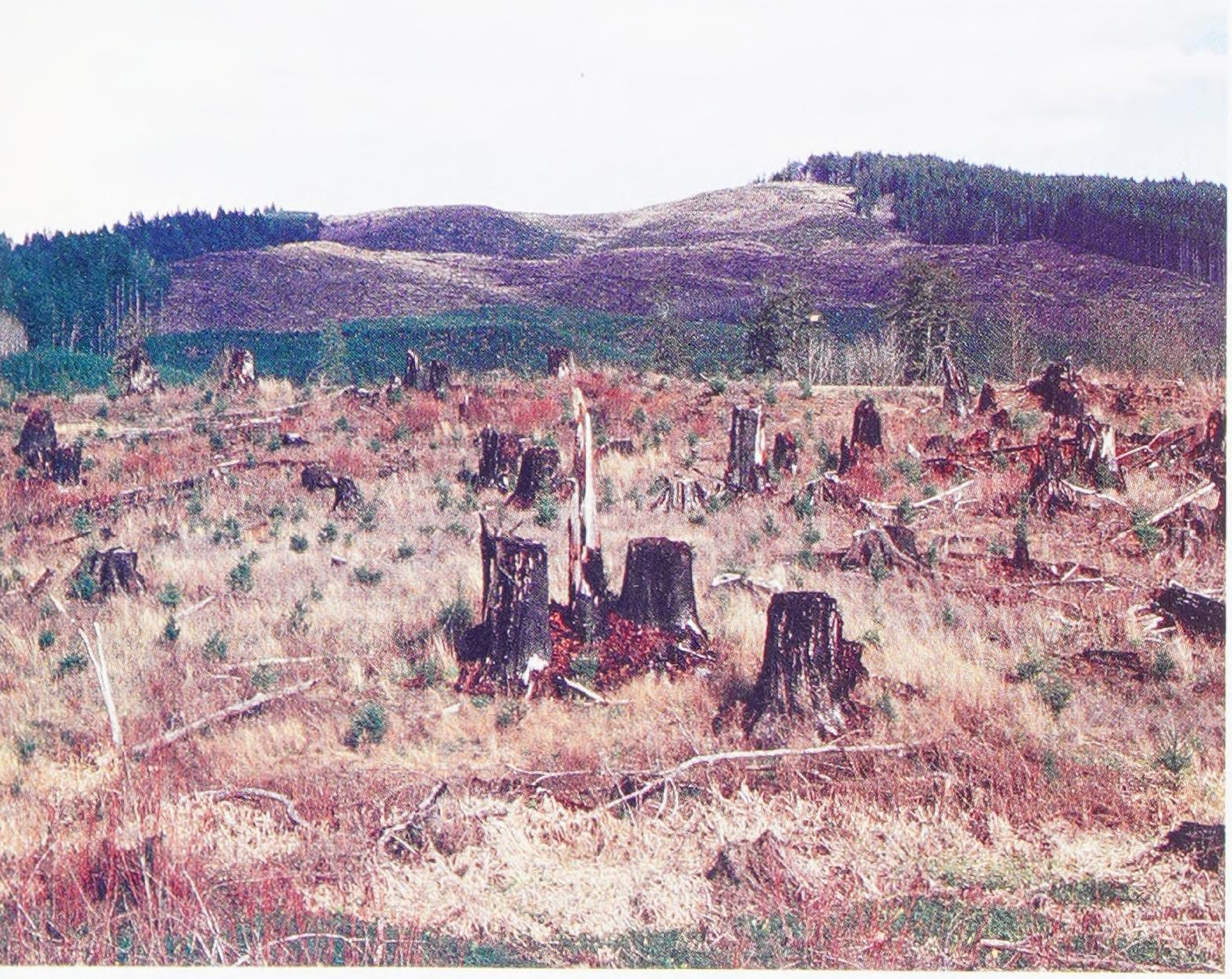
Where Have All the Frogs Gone?

Where have all the amphibians gone? That's what scientists all over the world are wondering. They have noticed a decline in the populations of toads, frogs, and salamanders in places like the United States, Costa Rica, Japan, and Australia. Yosemite toads, leopard frogs, and chorus frogs are a few of the many species of amphibians now in danger of becoming extinct.

What's causing this decline of amphibians? In 1990, a meeting of scientists was called by the National Academy of Science to discuss the problem. A variety of possible factors was suggested.

Some scientists think that the changes people have made in our environment are responsible for this disappearing act. Destruction of native habitats is likely to be a contributing factor. Amphibians typically require moist habitats to breed. With the continual expansion of urban areas, drainage of wetlands, and with deforestation, suitable breeding areas for many types of amphibians are becoming very limited. In the northwestern United States where thousands of acres of forest have been clear-cut, or completely cleared of trees, scientists report noticeably fewer frogs than in unlogged areas.

Figure 15-10. Many amphibian habitats are being lost due to the clear-cutting of forests.



Industry and automobiles contribute to acid rain and snow, which can kill salamander eggs as well as forests . Other possible causes of amphibian extinction include pesticides and the introduction of amphibian-eating game fish to new locations. In addition, countries like Indonesia, India, and Malaysia provide huge amounts of frog legs to satisfy the appetites of many people. Although drought may be a natural cause of this loss of amphibians, people may be playing a major role.

Because of the way amphibians live, it makes sense that they would be very sensitive to pollutants in the environment. They live mostly in water or in damp soil. They have no scales or shells for protection. And because their skin absorbs oxygen, poisonous gases and chemicals can also be absorbed. For this reason amphibians are considered **biological indicators**—species that reflect the condition of the environment.

What can be done? Amphibians are the source of food for many birds, mammals, fish, and reptiles. They also feed on many insects and other invertebrates. Will enough species be able to survive to prevent a major disturbance in the world's food chain?

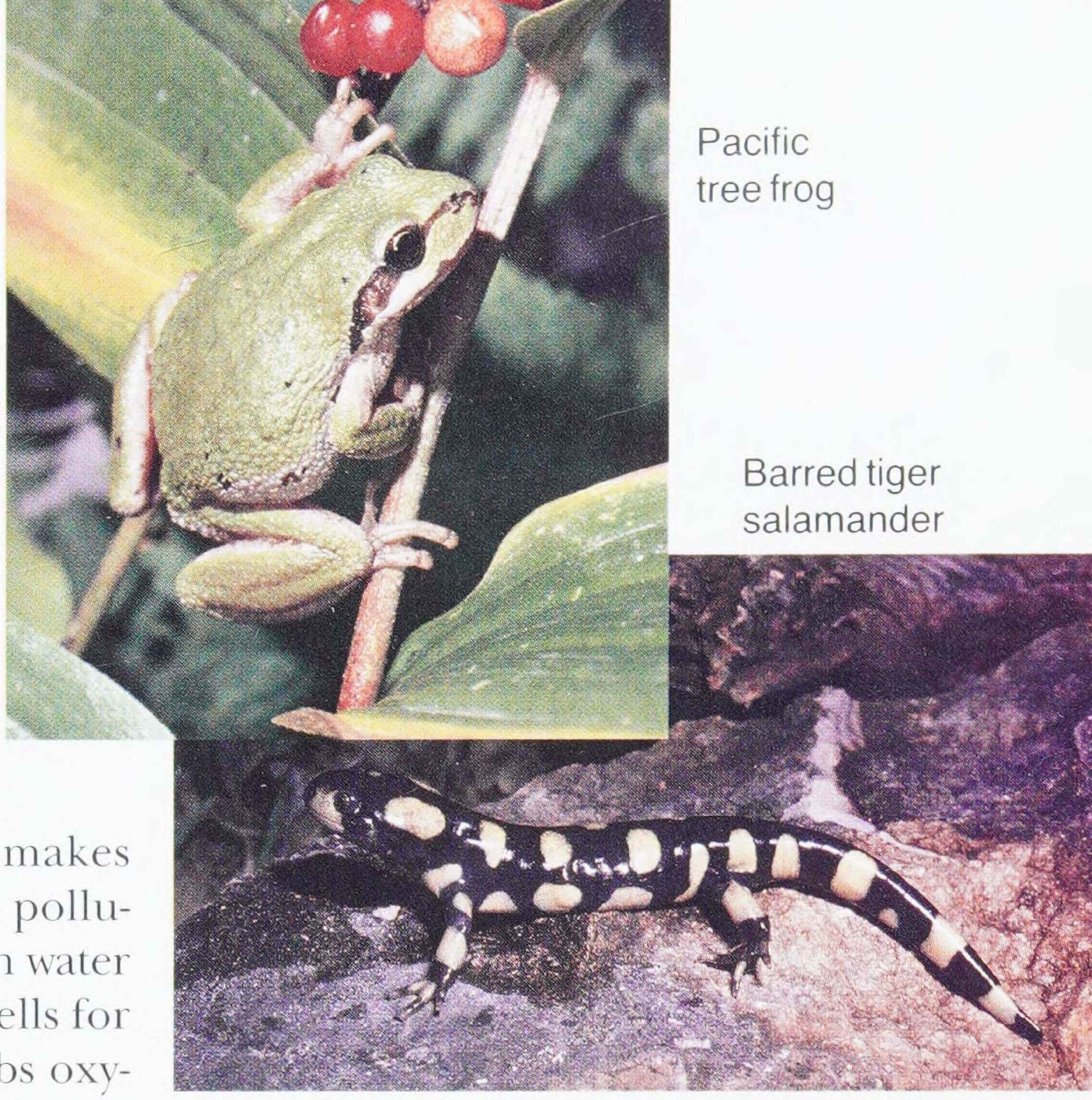


Figure 15-11. Many species of frogs and salamanders are endangered by human activities.

SECTION REVIEW

1. What two current environmental problems may be contributing to the decline in amphibian populations?
2. Why are amphibians more likely to be affected by acid rain than reptiles, which also often live in the water?

Connect to... Earth Science

Find out what took place during the Devonian and Carboniferous periods when amphibians became successful on Earth.

You Decide!

SCIENCE & SOCIETY

Many environmentalists think that the clear-cutting of forests in the northwestern United States is too destructive to be continued. Some scientists have found half the number of amphibians in logged areas as compared to unlogged areas. However, many people depend on logging to support their families. Without the logging industry, the economy of many areas would be ruined. What do you think the answer to this problem is?

ACTIVITY 15-2

Metamorphosis in Frogs

Problem: *How long does it take for a tadpole to develop into a frog?*

Materials

- 4-L aquarium or jar
- frog egg masses
- lake or pond water
- stereoscopic microscope
- watch glass
- small fishnet
- aquatic plants
- washed gravel
- boiled lettuce

Procedure

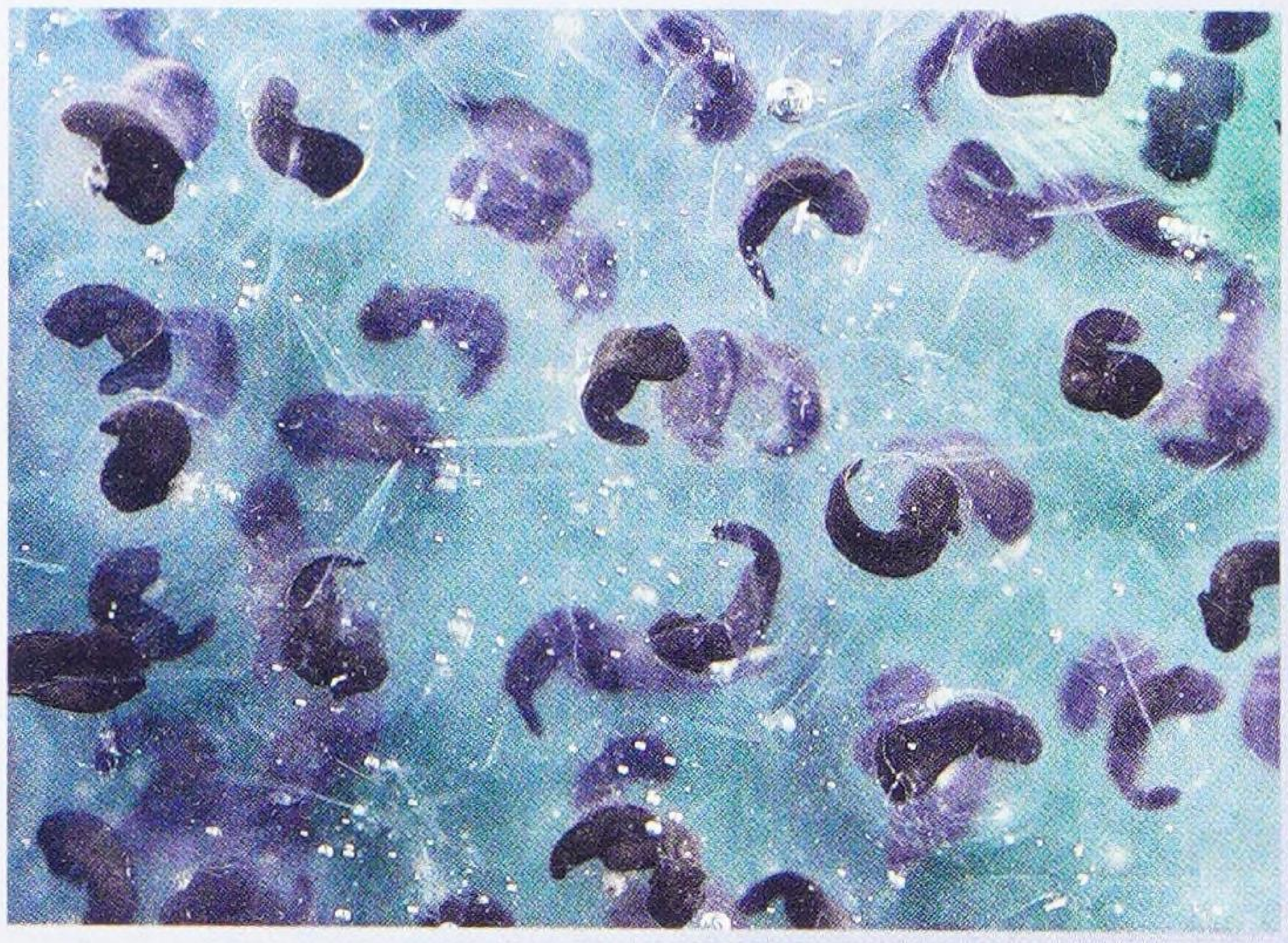
1. Collect a mass of frog eggs and 4 L of water from a lake or pond.
2. Prepare an aquarium with gravel, the pond water, and five or six aquatic plants.
3. Place the egg mass in the aquarium. Use the fishnet to obtain a few eggs and place the eggs in a watch glass. The eggs should have the dark side up and the white yolk down. **CAUTION:** *Handle the eggs with care.*
4. Observe the eggs and record your observations in the data table.
5. *Observe* the eggs twice each week and *record* any changes that you observe.
6. When the tadpoles hatch, observe the stages of development twice a week. Identify the fin on the back, mouth, eyes, gill cover, gills, nostrils, hind and front legs. Feed the tadpoles boiled lettuce. Observe how they feed.

Analyze

1. How long does it take for the eggs to hatch?
2. How long does it take for a tadpole to develop legs?
3. What organs do tadpoles have for breathing?
4. Which pair of legs appears first?

Conclude and Apply

5. What is the advantage of the jellylike coating around the eggs?
6. *Compare* the eyes of the young tadpoles with the eyes of the older ones.
7. Why are plants needed in the aquarium?
8. Are tadpoles plant-eaters or meat-eaters?
9. How long does it take for a tadpole to develop into a frog?



Data and Observations

Date	Observations

Reptiles

15-4

Objectives

- Identify the adaptations that enable reptiles to live on land.
- Infer why the early reptiles were so successful.
- Describe the characteristics of the modern reptiles.

New Science Words

reptile
amniote egg

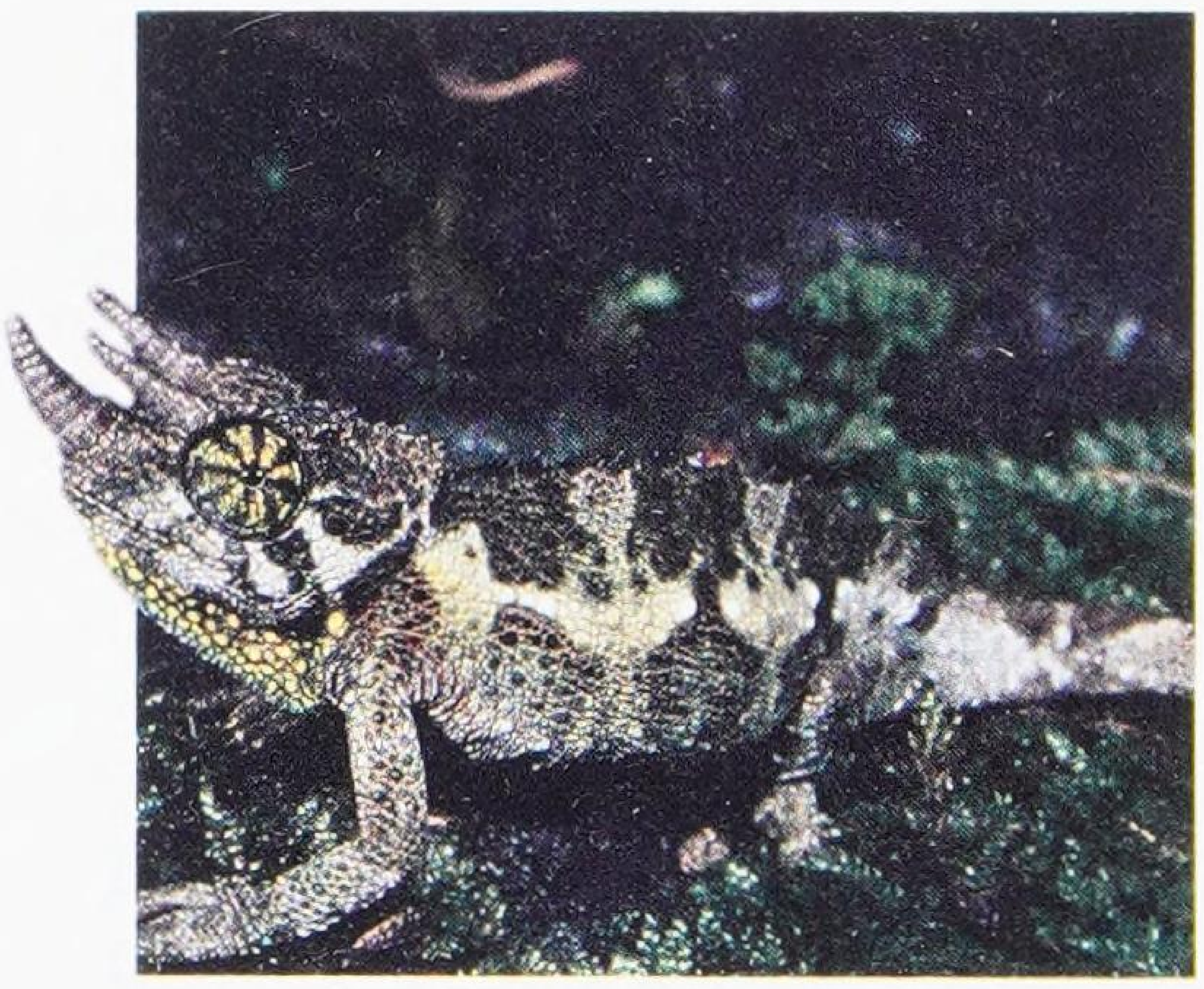
What Is a Reptile?

The class Reptilia includes lizards, snakes, turtles, crocodiles, and alligators. They have many characteristics that are adaptations for life on land. A thick, dry, waterproof skin covered with scales prevents drying out and injury. With the exception of snakes, reptiles have four legs with claws that hold the body off the ground for moving quickly. The claws are used to dig, climb, and run.

Remember from the last section that even though amphibians live on land, they still need water for respiration and reproduction. Scientists hypothesize that, over time, some amphibians became less dependent on water and became the ancestors of reptiles. A **reptile** can be described as a cold-blooded vertebrate with a dry, scaly skin that lays eggs covered with a leathery shell.

Reptiles vary greatly in size, shape, and color. There are giant pythons longer than 10 meters that can swallow crocodiles whole. Some sea turtles have a mass of more than 0.9 metric tons and can swim faster than you can run. Three-horned lizards have movable eye sockets and tongues as long as their bodies. Reptiles live on every continent except Antarctica and in all the oceans except those in the polar regions.

Reptiles breathe with lungs. Even turtles that live in water must come to the surface to breathe air. A reptile's heart has three chambers. The lower chamber is partially divided. Oxygen-rich blood coming from the lungs is kept separated from blood that contains carbon dioxide returning from the body. This type of circulatory system provides a lot of oxygen to all parts of the body. Remember that oxygen is needed to release energy by cell respiration.



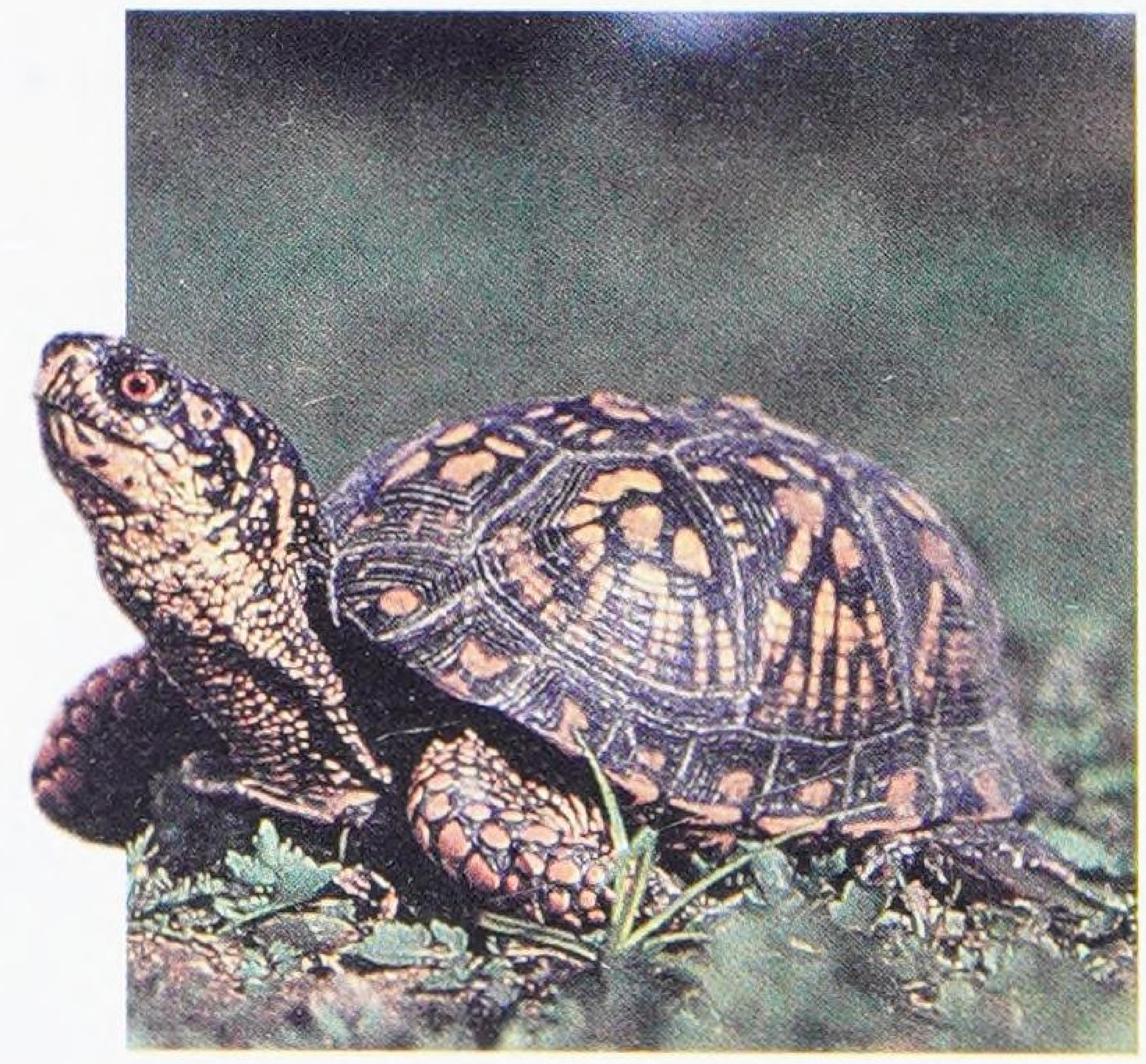


Figure 15-12. A three-horned lizard, top, and an Eastern box turtle, bottom, are both reptiles.

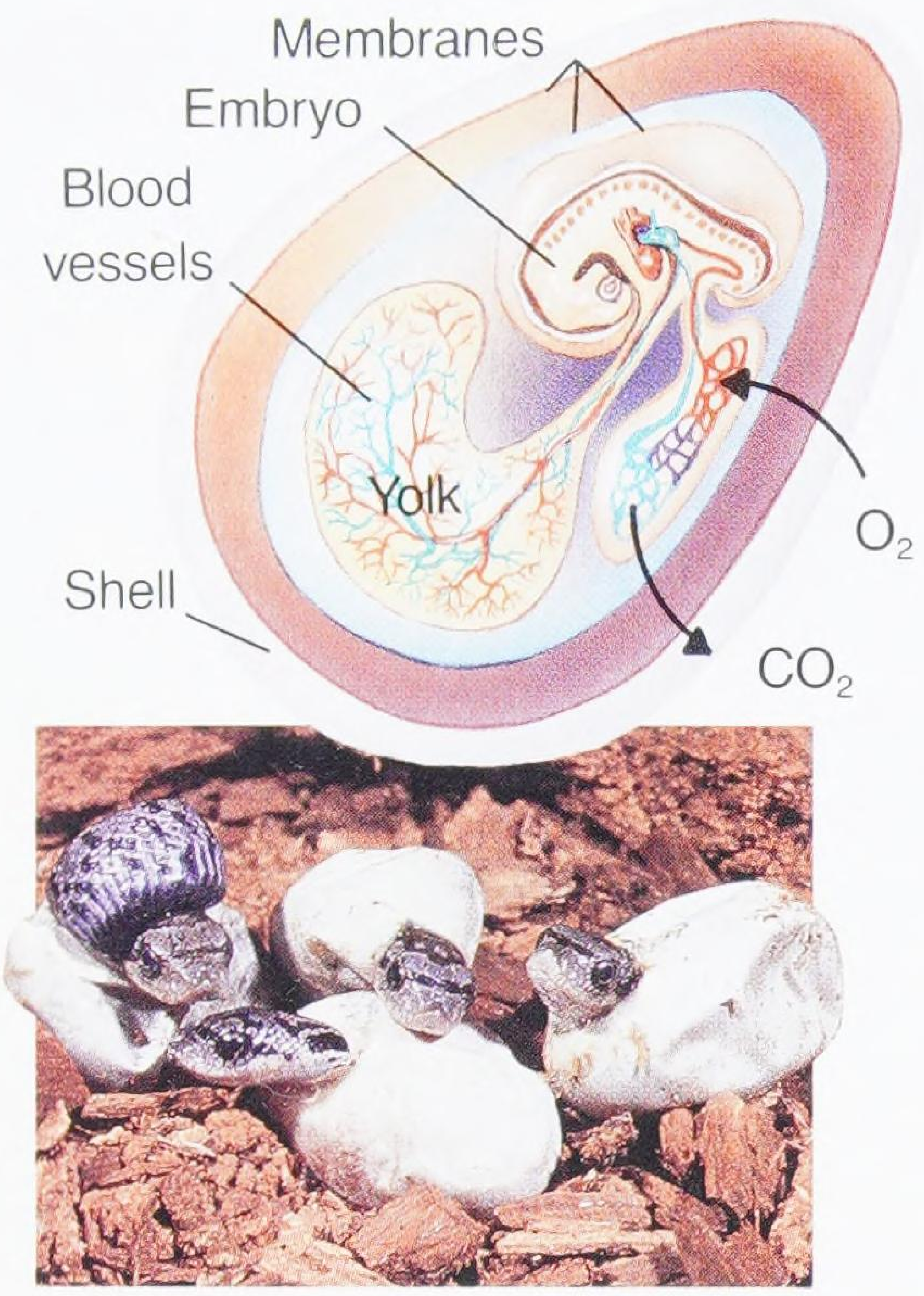


Figure 15-13. The amniote egg, top, is one of the adaptations reptiles have for living on land. Above, young reptiles hatch from their eggs fully developed.

One of the most important adaptations of reptiles for living on land is the way they reproduce. Unlike the eggs of fish and amphibians, eggs of reptiles are fertilized internally, inside the body of the female. After fertilization, the female secretes a leathery shell around each egg, and then lays the eggs on land.

Figure 15-13 shows the structures in a reptile egg. The egg provides a complete environment for the embryo to develop in. This type of egg, called an **amniote egg,** contains membranes to protect and cushion the embryo, and to help it get rid of wastes. It also contains a large food supply, the yolk, for the embryo to use as it develops. Small holes in the shell, called pores, allow oxygen and carbon dioxide to be exchanged. By the time it hatches, a young reptile looks like a small adult.

Have you ever been hiking and seen the dry outer layer of skin a snake has left behind? Many snakes and other reptiles molt from time to time, depending on how fast they grow. The skin is a good source of protein so they often eat it after molting.

Origin of Reptiles

Reptiles evolved slowly over a period of millions of years. During the Mesozoic Era, they came to dominate Earth. The Mesozoic Era, which lasted over 160 million years, is known as the Age of the Reptiles. Many species emerged from the earliest reptiles called cotylosaurs (KAHD uh luh sahrs). As their numbers increased, some returned to the water to find a place to live. Others protected themselves with large, heavy, scale-like plates and speed. At least two species of flying reptiles developed.

The ancient reptiles were very successful. Why, then, did they die off? Scientists have developed many hypotheses to explain this disappearance. One is that the climate cooled toward the end of the Cretaceous Period, and it became too cold for the dinosaurs. They were too large to hibernate and had no body covering for protection. Another theory is that the explosion of a nearby star gave off dangerous radiation and caused cold, unfavorable weather for thousands of years. There are several other hypotheses to explain the disappearance of dinosaurs. Many scientists suggest that no one theory completely explains why the dinosaurs died.

In Your JOURNAL

There is no one convincing answer that explains the disappearance of the dinosaurs from Earth. Research this subject and choose the theory you most agree with. **In your Journal,** write a report explaining the theory and why you chose it.

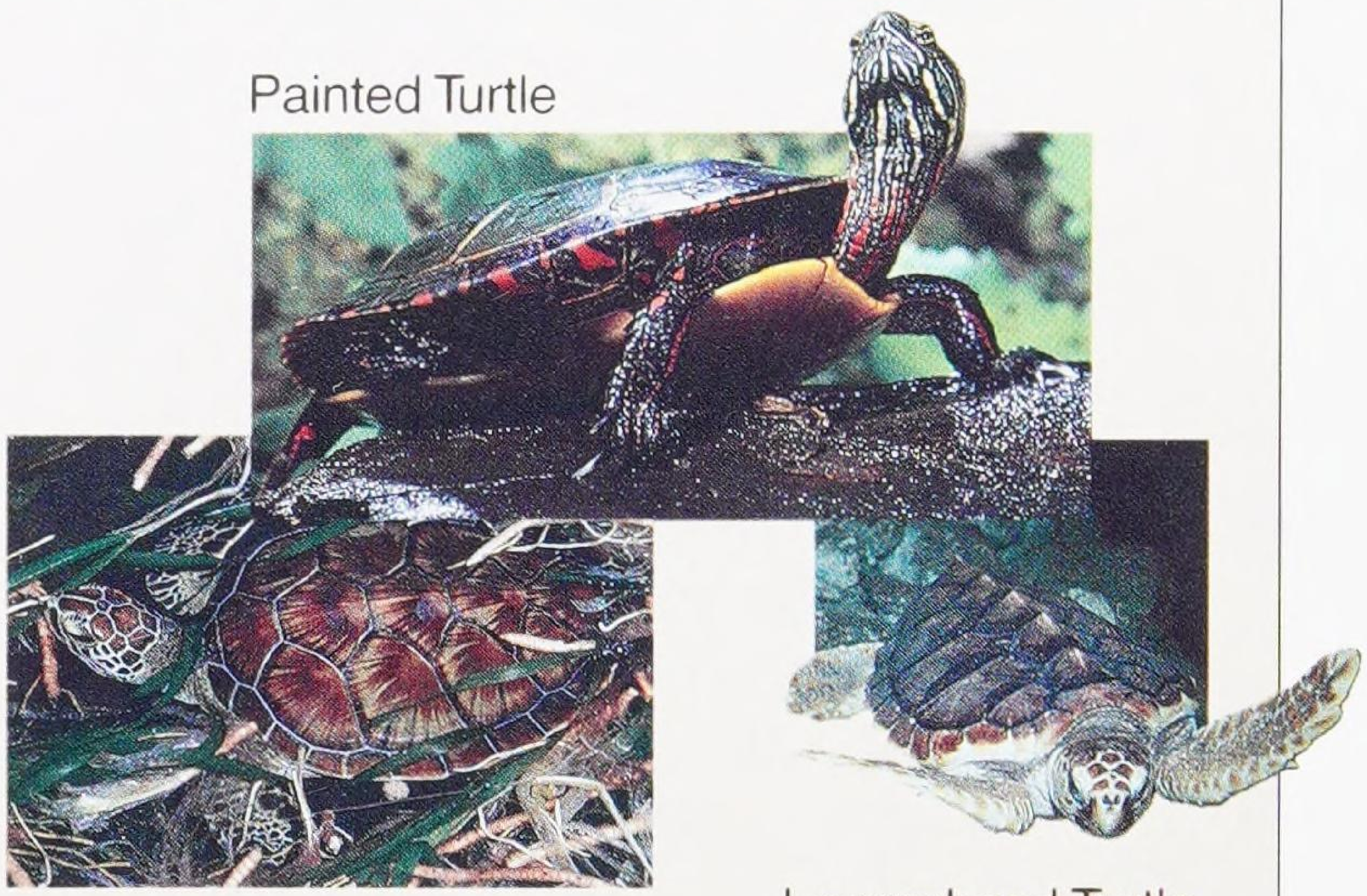
Modern Reptiles

Modern reptiles probably descended from similar amphibian ancestors. Today there are three orders of reptiles: turtles; crocodiles and alligators; lizards and snakes.

Table 15-1

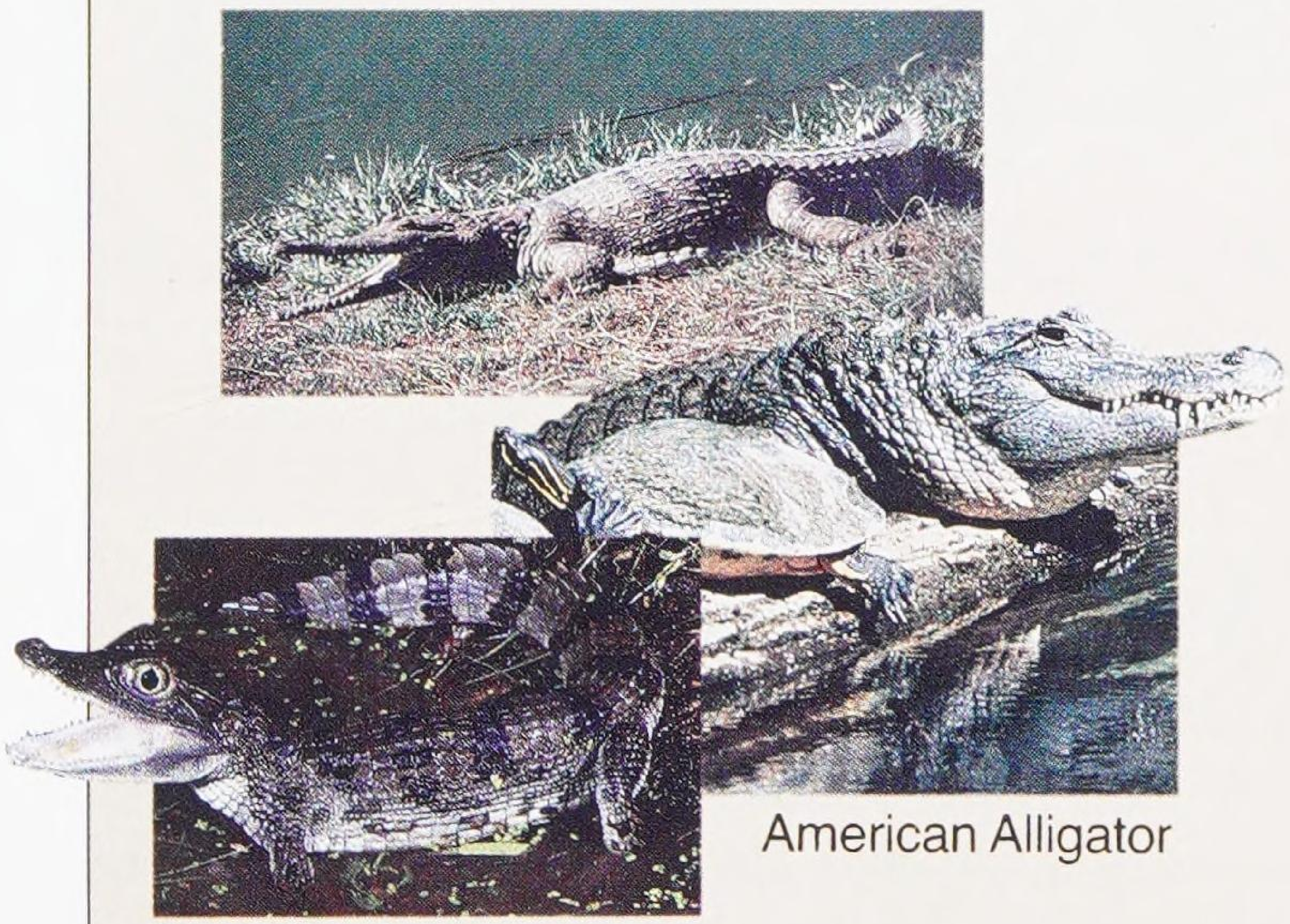
ORDERS OF MODERN REPTILES

Turtles
Turtles make up a very successful order of animals. They can be found on almost every continent and in most of the world's oceans. The body of a turtle is covered by a hard shell on both top and bottom. Most turtles can withdraw into their shell for protection. Turtles have no teeth and use their beaks to feed on insects, worms, fish, and plants.


Painted Turtle

Green Turtle

Loggerhead Turtle

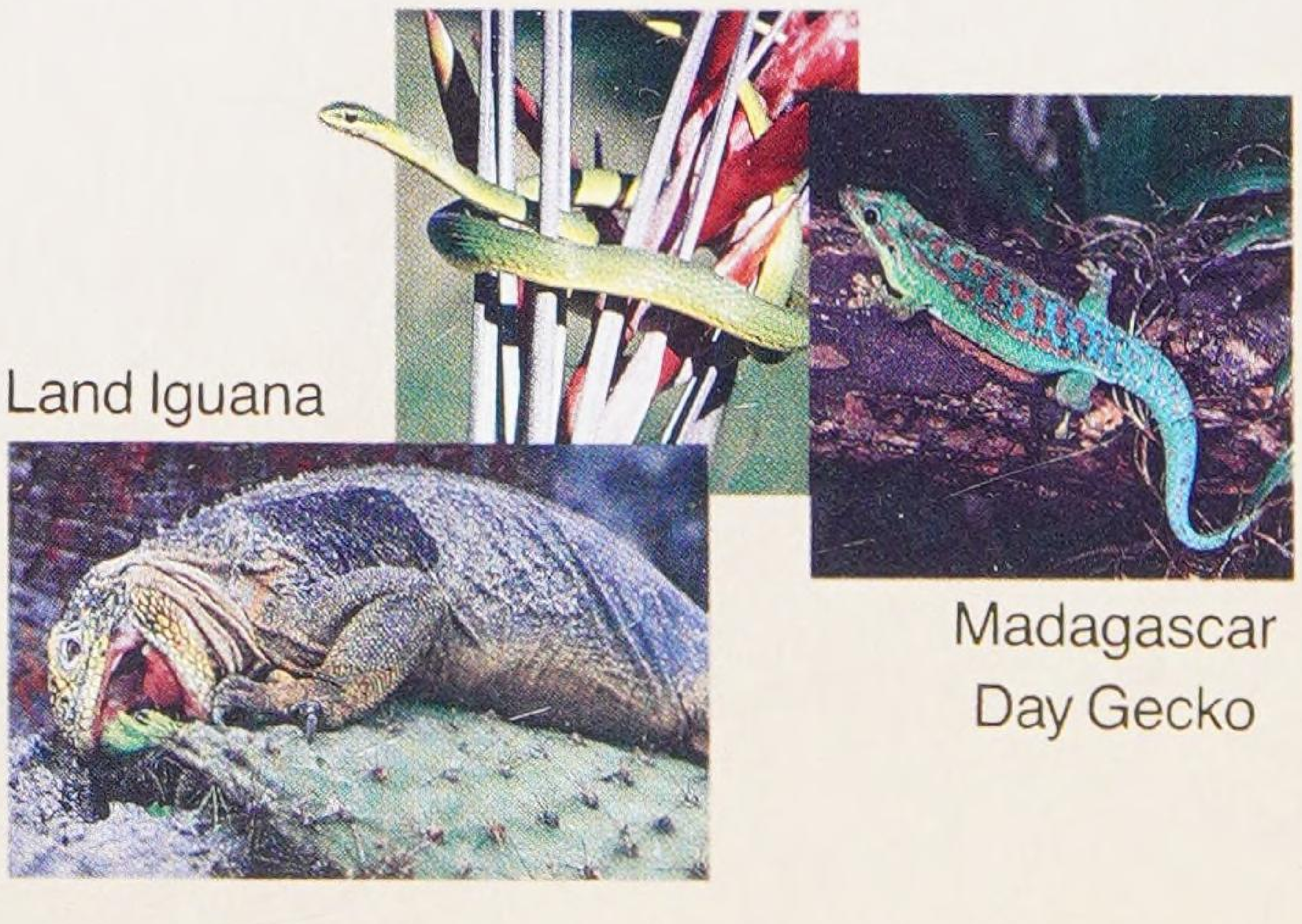

Johnston's Crocodile

American Alligator

Speckled Caiman

Crocodiles and Alligators
Crocodiles and alligators are among the world's largest living reptiles. They make up the order Crocodilia. Members of this order can be found in or near water in tropical climates. Crocodiles have long slender snouts and are very aggressive. They can attack animals as large as cattle. Alligators are less aggressive. They have broad snouts and feed on fish, turtles, and waterbirds.

Lizards and Snakes
Lizards and snakes make up the largest group of reptiles. Lizards have moveable eyelids, external ears, and legs with clawed toes on each foot. They feed on reptiles, insects, spiders, worms, and mammals. Snakes don't have legs, eyelids, or external ears. Snakes are meat-eaters. Some snakes wrap around and constrict their prey. Others inject their prey with poison venom. Many snakes feed on rodents and help control their populations.


Rough Green Snake

Land Iguana

Madagascar Day Gecko

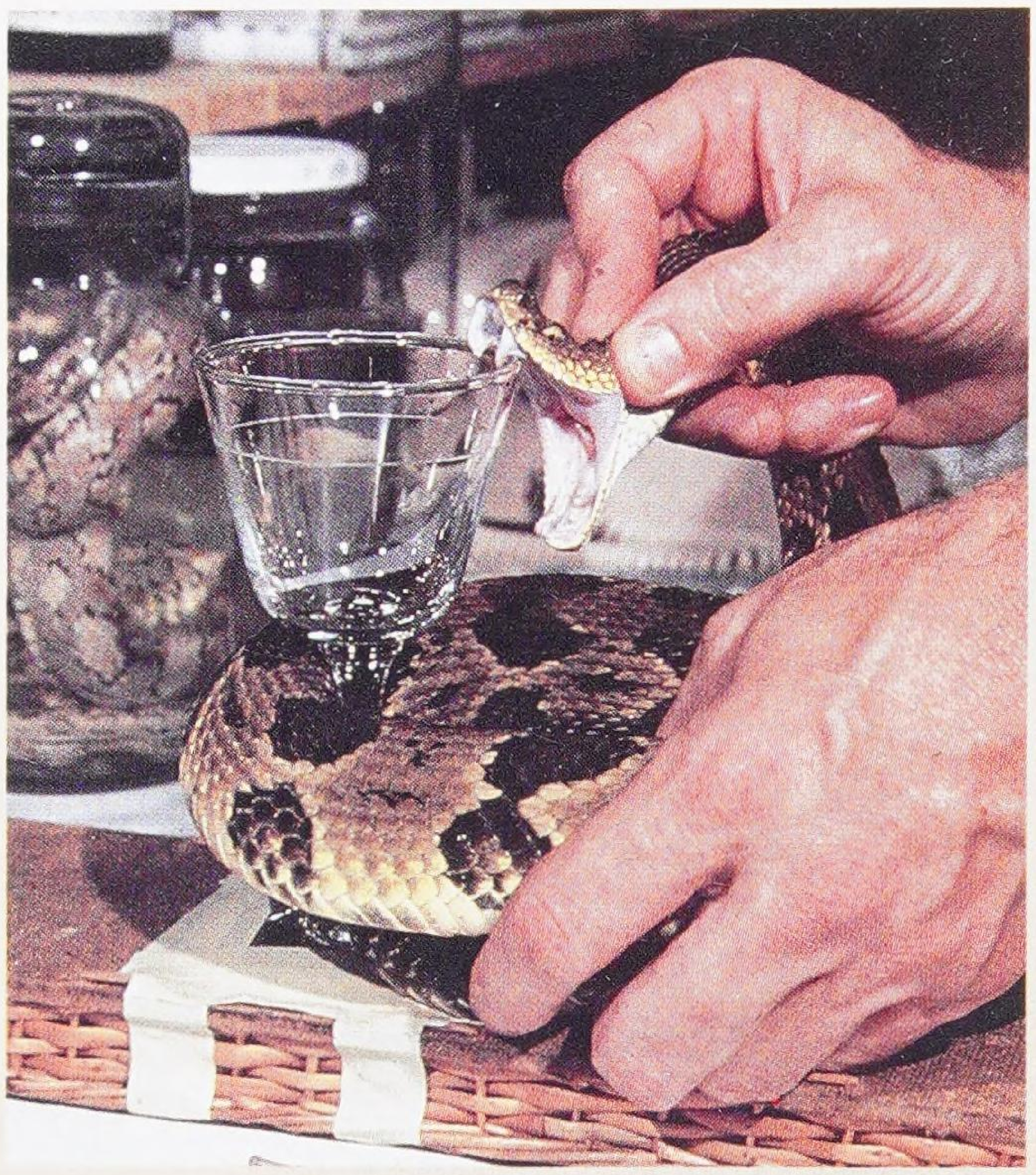
TECHNOLOGY

Snake Oil Medicines

Scientists are finding potential medicines in unusual places. Ancrod, an ingredient in the venom of Malayan pit vipers, may help human stroke victims. Ancrod is a substance that stops blood from clotting. The victim of the pit viper dies from the large dose of ancrod it receives. In the correct doses, ancrod can prevent the damage of strokes caused by blood clots that block blood vessels in the brain of a human.

The snake venom is collected from the snakes by pressing their upper jaw against the top of a container. This causes the venom to drip from the snake's fangs.

Think Critically: About how long after a stroke would this treatment need to be tried to be successful?



SECTION REVIEW

1. What adaptations do reptiles have for living on land?
2. Describe the ancient reptiles.
3. How do turtles differ from other groups of reptiles?
4. Explain how snakes are different from lizards.
5. **Apply:** Poisonous coral snakes and some harmless snakes have bright red, yellow, and black colors. How is this an advantage to nonpoisonous snakes?
6. **Connect to Chemistry:** Snake venom contains poisonous proteins or toxins. What do you think hemotoxins and neurotoxins attack?

Skill Builder

☑ Concept Mapping

Make a concept map showing the major characteristics and orders of the reptile class. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

CHAPTER REVIEW

SUMMARY

15-1: Fish

1. The phylum Chordata includes lancelets, tunicates, and vertebrates: all have a notochord, dorsal nerve cord, and gill slits.

2. Warm-blooded animals maintain a constant body temperature. The body temperature of a cold-blooded animal changes with its environment.

3. Classes of fish include jawless fish, cartilaginous fish, and bony fish.

15-2: Amphibians

1. Amphibians are cold-blooded vertebrates that live both in water and on land. The adaptations of amphibians include moist skin, mucus glands, and lungs.

2. Frogs live in wet areas, have jumping legs, and sensory organs. Toads live in drier areas and have hopping legs. Salamanders have smooth, moist skin and short legs.

3. Frogs go through metamorphosis from egg, to tadpole, to adult. Legs develop, lungs replace gills, and the tail is lost.

15-3: Science and Society: Amphibian Population Decline

1. Amphibian populations are declining due to habitat destruction, acid rain, pesticides, and predation.

2. Amphibians are sensitive to pollution because they have no scales or shells for protection. They also absorb materials through their skin, including pollutants.

15-4: Reptiles

1. Reptiles are true land animals having dry, scaly skin. They lay amniote eggs with leathery shells.

2. Early reptiles were successful because of their adaptations to living on land.

3. Reptile groups include turtles with tough shells, meat-eating crocodiles and alligators, and the largest group including snakes and lizards.

KEY SCIENCE WORDS

a. **amniote egg**
b. **amphibians**
c. **biological indicators**
d. **cartilage**
e. **chordates**
f. **cold-blooded**
g. **dorsal nerve cord**
h. **endoskeleton**
i. **estivation**
j. **fins**
k. **fish**
l. **gill slits**
m. **hibernation**
n. **notochord**
o. **predator**
p. **prey**
q. **reptile**
r. **scales**
s. **warm-blooded**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. dorsal structure that becomes the backbone
2. cold-blooded land and water animals
3. the internal skeleton
4. tough, flexible tissue
5. organism that kills others for food
6. inactivity in winter
7. inactivity in summer
8. cold-blooded organisms with dry skin
9. fanlike steering structures in fish
10. species that reflect the condition of the environment.

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. Animals that have fins, scales, and gills are _______.
   a. amphibians c. reptiles
   b. crocodiles d. fish

2. Jawless fish do not have _______.
   a. cartilage c. slimy skin
   b. scales d. long tubelike bodies

3. An example of a cartilaginous fish is a ______.
   a. hagfish c. perch
   b. lamprey d. shark

4. Most fish species belong to the _______ group.
   a. osteichthyes c. cartilaginous
   b. jawless d. chondrichthyes

5. A fish with both gills and lungs is a _______.
   a. shark c. lungfish
   b. ray d. perch

6. The group of vertebrates with lungs and moist skin is _______.
   a. amphibians c. reptiles
   b. fish d. lizards

7. A _______ is *not* a reptile.
   a. lizard c. snake
   b. turtle d. salamander

8. The largest group of reptiles includes lizards and _______.
   a. snakes c. crocodiles
   b. turtles d. alligators

9. Reptiles lay _______ eggs.
   a. amniote c. jelly-like
   b. brown d. hard-shelled

10. At some time in their lives, all _______ have a notochord, dorsal nerve cord, and gill slits.
    a. echinoderms c. arthropods
    b. mollusks d. chordates

USING LAB SKILLS

11. In Activity 15-1, you determined how water temperature affects fish. Place a small drop of slightly diluted food coloring in front of the mouth of a goldfish or guppy. Where does the colored water come out? How long does it take to appear?

12. In Activity 15-2, you observed metamorphosis in frogs. Based on your observations, what evidence do you have that frogs are adapted for life on land and tadpoles are adapted for living in water?

THINK AND WRITE CRITICALLY

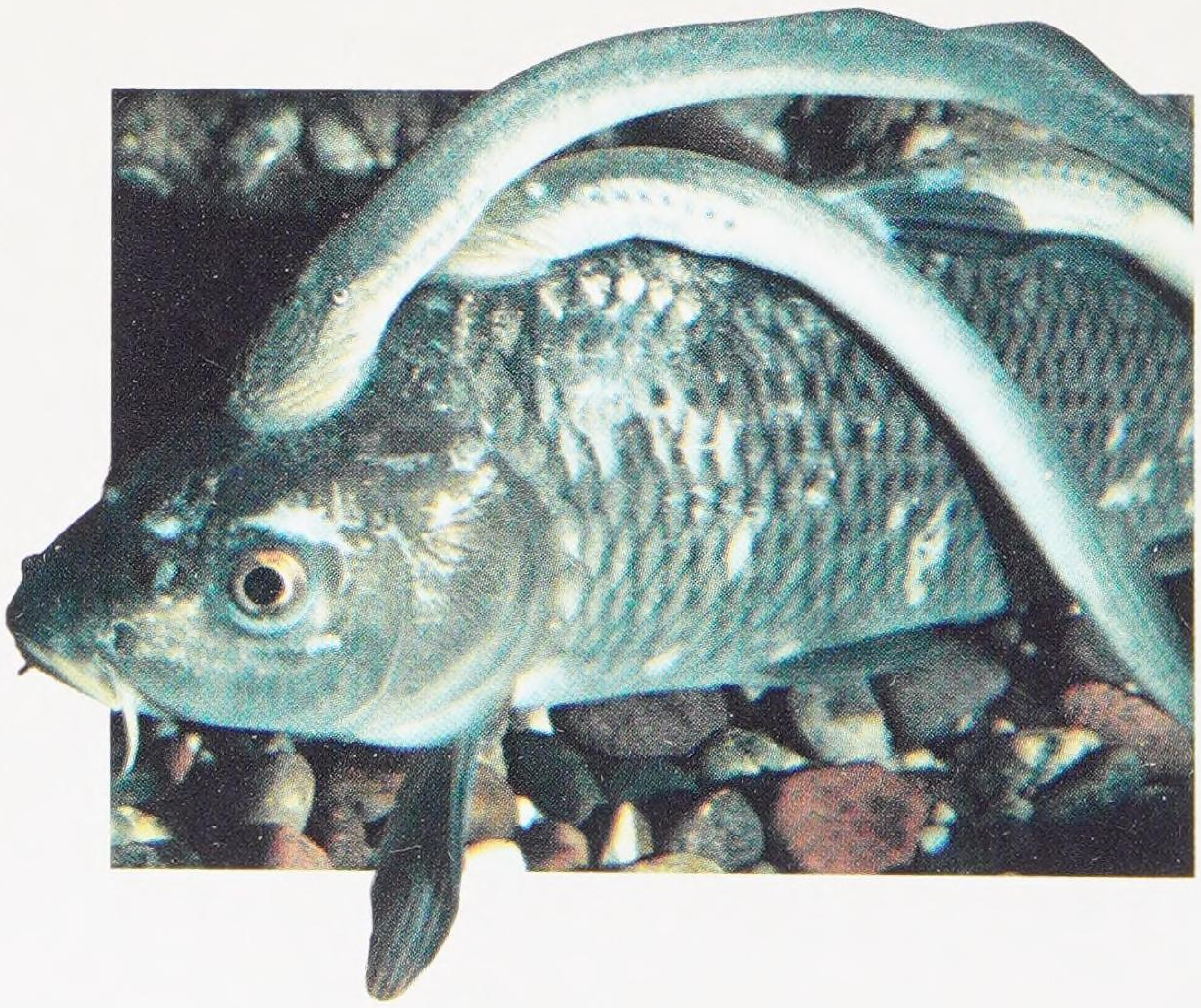
Answer the following questions in your Journal using complete sentences.

13. Describe the structural adaptations that allow fish to live in water.

14. Explain why a lamprey is a predator.

15. Compare and contrast the adaptations of amphibians and reptiles to life on land.

16. Describe the life cycle of a frog.



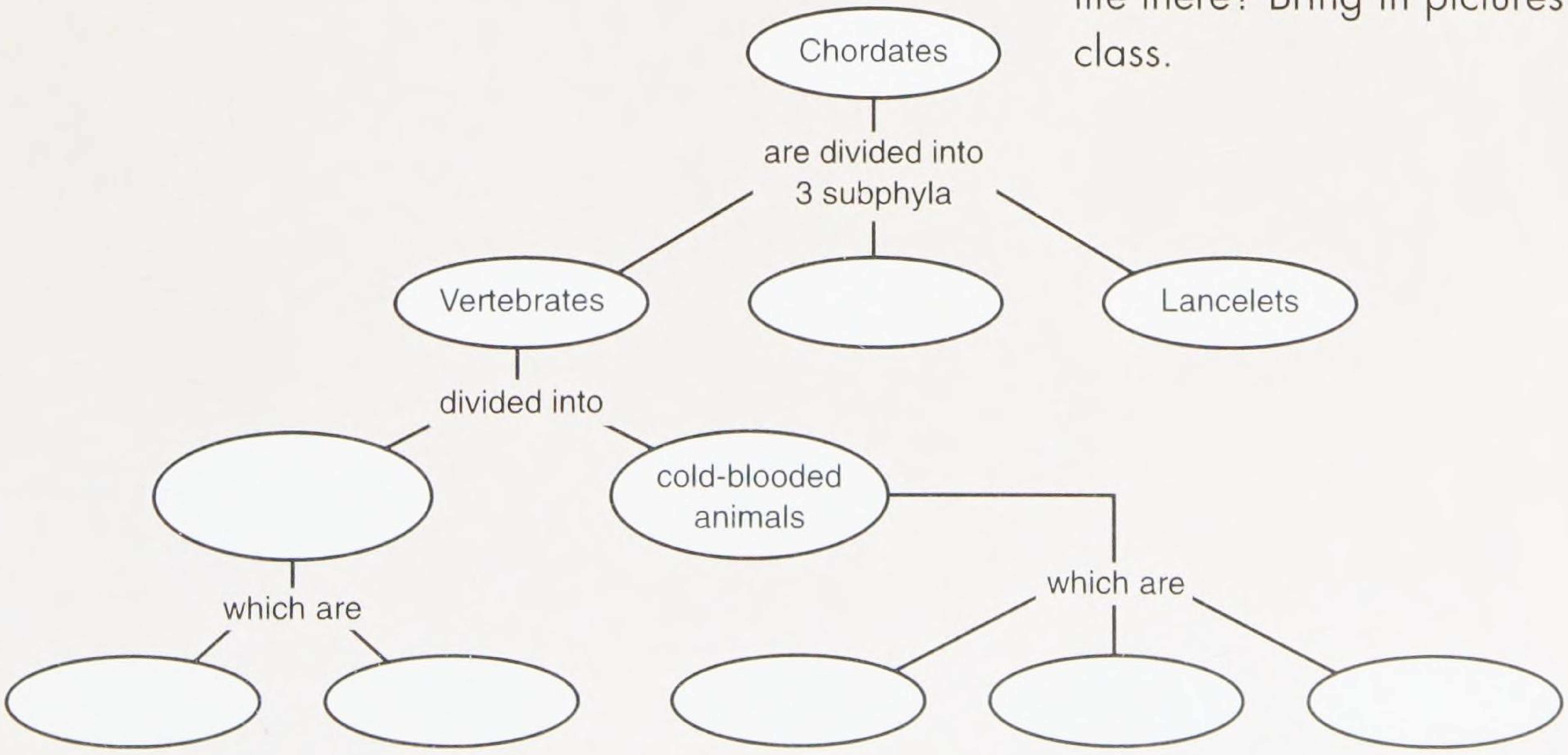
APPLY

17. Why do you think there are fewer species of amphibians on Earth than any other type of vertebrate?
18. What is the advantage of the amniotic egg over the eggs laid by amphibians?
19. Why are amphibians considered biological indicators?
20. In what ways are tunicates similar to sponges?
21. What features are common to all vertebrates?

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Sequencing:** Sequence the order in which these structures appeared in evolutionary history and explain what type of organism had this adaptation and why: skin has mucus glands; skin has scales; fins used for movement; dry, scaly skin
2. **Concept Mapping:** Complete the concept map below describing the chordates.



3. **Comparing and Contrasting:** Make a chart comparing the features of fish, amphibians, and reptiles.
4. **Designing an Experiment:** Design an experiment to find out the effect of water temperature on frog egg development.
5. **Making and Using Graphs:** Make a pie graph of the species of fish in the table below.

Classes of Fish	# of Species
Jawless Fish	45 species
Chondrichthyes	275 species
Osteichthyes	25 000 species

PROJECTS

1. Check the local library or nature center and find out what kinds of amphibians and reptiles are common in your area. Arrange for a local naturalist to visit class with representative animals from your area.
2. Study the tropical rain forests' amphibians. What special adaptations do they have for life there? Bring in pictures to share with the class.

CHAPTER

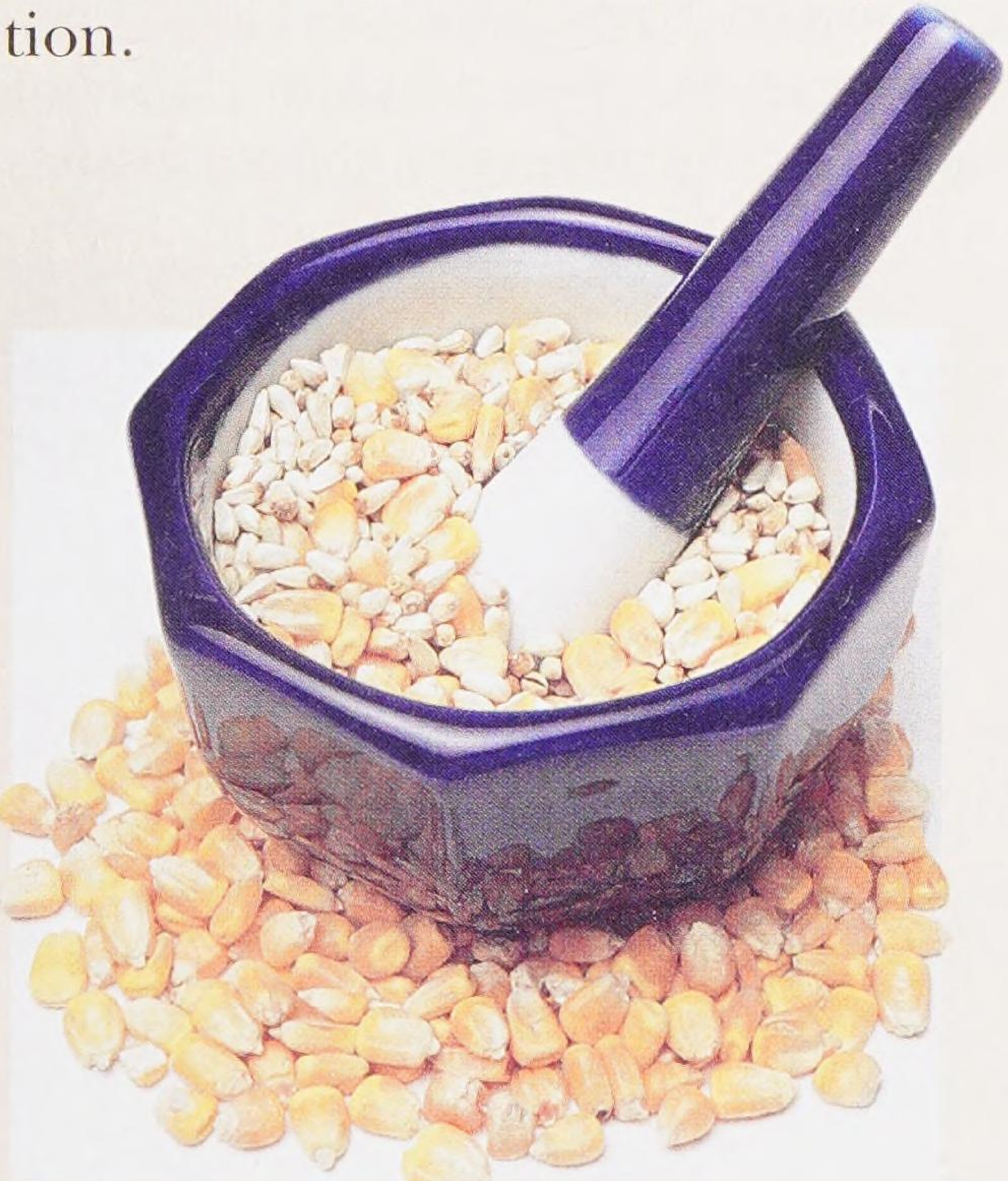
16 Warm-Blooded Animals

Have you ever watched birds eat from a feeder? If you have, you know that they eat one seed after another without stopping. Birds don't chew their food before swallowing, as you do. They don't have teeth, but they do have a muscular grinding sac called a gizzard. How does the gizzard work?

FIND OUT!

Do this simple activity to find out how a bird's gizzard works.

Place some cracked corn, birdseed, sunflower seeds, nuts, and some gravel in a mortar. Use a pestle to grind the seeds. What do the seeds look like now? A bird's gizzard works in much the same way. The gizzard has no teeth, but contains gravel to crush the food. *Infer* how a bird's gizzard helps in digestion.



Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 16-1 Birds
- Characteristics of Birds
- Kinds of Birds
- Origin and Importance of Birds

Section 16-2 Mammals
- Characteristics of Mammals
- Kinds of Mammals
- Origin and Importance of Mammals

Section 16-3 Science and Society
Saving the Manatee
- "Sea Cows"?!
- The Future of Manatees

Previewing Science Skills

- In the **Skill Builders,** you will compare and contrast, and classify.
- In the **Activities,** you will observe, experiment, infer, and classify.
- In the **MINI-Labs,** you will observe, infer, and describe.

What's next?

In this chapter, you'll learn more about birds. You'll learn how they are adapted for flight and how they live. You'll also learn about mammals, the class to which you belong. You will learn how mammals are classified and how they live.

16-1 Birds

New Science Words

incubate
contour feathers
down feathers
preening

Objectives

- Identify the characteristics of birds.
- Identify the adaptations birds have for flight.
- Explain how birds reproduce and develop.

Characteristics of Birds

There probably isn't a day that goes by in which you don't see a bird. Birds are found on rooftops, backyards, city streets, and in farmers' fields. What are the characteristics that make a bird a bird? First, unlike cold-blooded reptiles and amphibians, birds are warm-blooded. Warm-blooded organisms maintain a constant body temperature. A bird's body temperature is about 40°C. You are warm-blooded also and maintain a body temperature of 37°C.

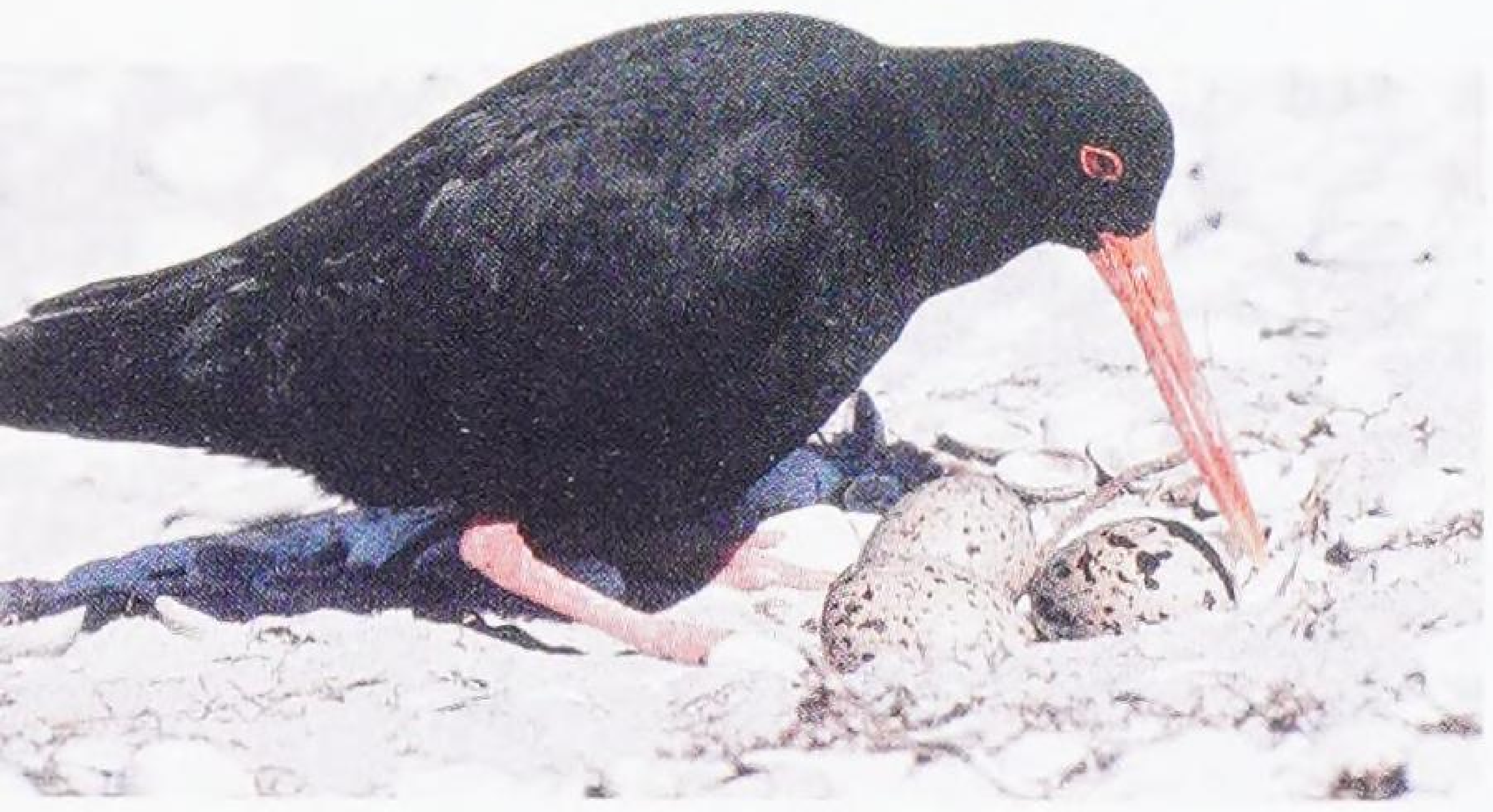


Figure 16-1. Birds are the only organisms with feathers. Most birds incubate their eggs until they hatch.

Second, birds have feathers and scales. They are the only members of the animal kingdom that have feathers. A third characteristic shared by all birds is they lay eggs enclosed in a hard shell. The parents keep the eggs warm, or **incubate** them, until they hatch. Fourth, the front legs of all birds are modified into wings. The two hind legs support the body and usually have claws.

People have always been fascinated by the ability of birds to fly. Now that you know the major characteristics of birds, let's look at the adaptations birds have for flight.

Adaptations for Flight

Flight requires a light, yet strong skeleton, wings, and feathers to help lift the bird off the ground. Keen senses, especially eyesight, and tremendous amounts of energy are also needed for flight.

A bird's body is covered with two types of feathers, contour feathers and down feathers. Strong, lightweight **contour feathers** give birds their coloring and smooth, sleek shape. These are the feathers birds use to fly. The long contour feathers on the wings and tail help the bird steer and keep from tipping over. Have you ever watched ducks swimming in a pond on a freezing cold day, and

In Your JOURNAL

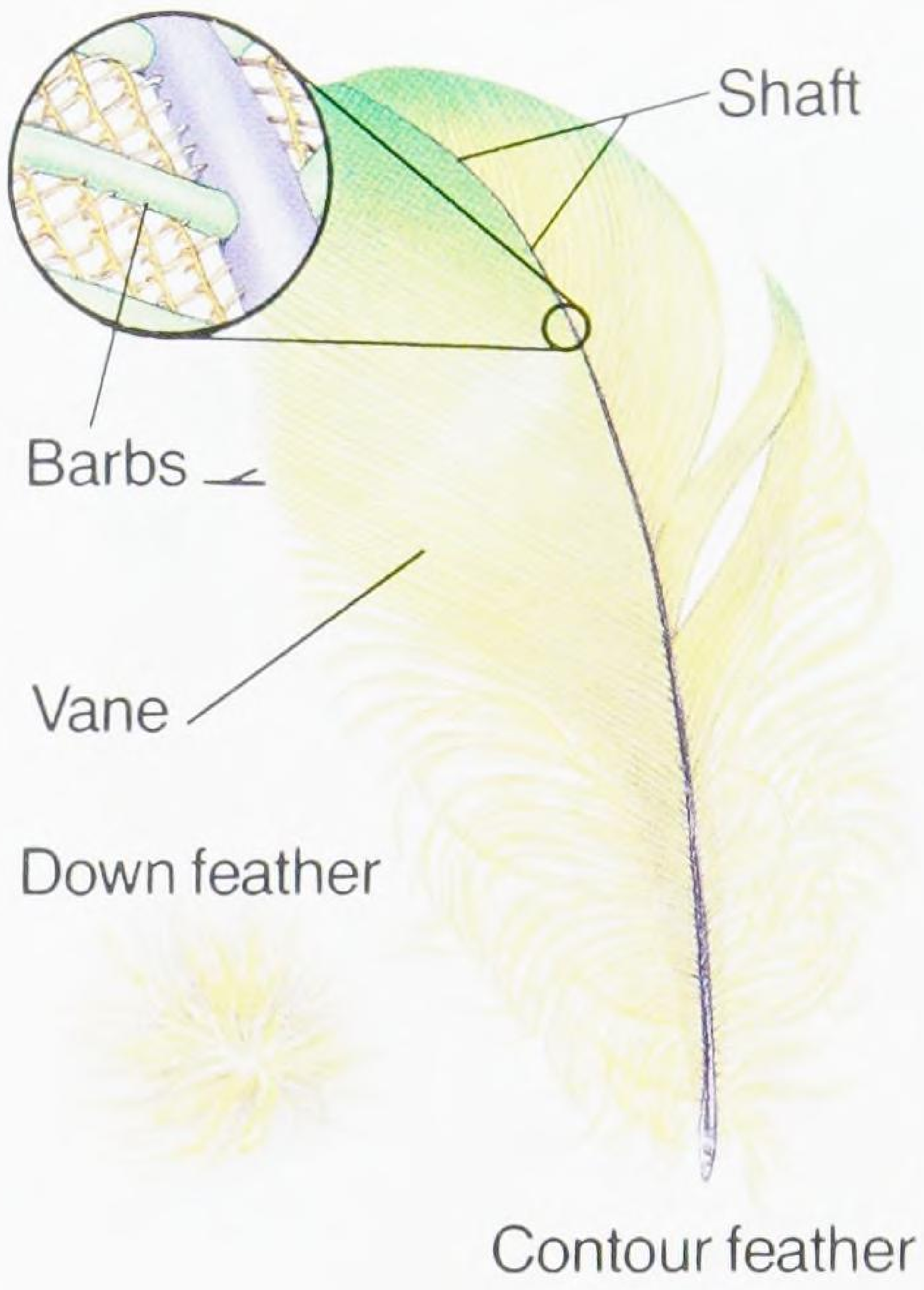
Form a group in your class to develop a bird-feeding plan for your area of the country. *Determine* which species you should be feeding. **In your Journal,** draw the kinds of feeders you will use. List the locations and kinds of food these birds will need.

wondered how they keep warm? Soft, fluffy **down feathers** provide an insulating layer next to the skin of adult birds and cover the bodies of young birds. Feathers help birds maintain their constant body temperature. They grow in much the same way as your hair grows. The base of each feather shaft is rooted in a tiny follicle and receives nutrients from the blood. When it is fully grown, the feather either falls off or is pushed out by a new feather. As you can see in Figure 16-2, the shaft of the feather has two vanes, each with many branches called barbs. Each barb has many cross braches that give the feather strength.

To care for its feathers, a bird has an oil gland located just above the base of its tail. Using its beak, the bird rubs oil from the gland over its feathers in a process called **preening.** The oil conditions the feathers and helps make them water repellent.

A bird sheds its feathers just as a reptile sheds its skin. Whereas a reptile sheds its skin all at once, a bird sheds and replaces its feathers a few at a time. The shedding of old feathers accompanied by the growth of new ones is called molting.

Flight requires that a bird have very sharp vision and hearing. Keen vision is necessary for taking off, landing, and hunting. For example, at night an owl can see a mouse on the forest floor from high in the branches of a tree. Acute hearing helps some species of bird locate prey, and it allows all birds to sense danger. Some of the adaptations birds have for flight can't be seen, because they are internal. One of these is a bird's skeleton. Many of the bones in a bird's skeleton are fused for extra strength and more stability for flight. To make a bird lighter, most of its bones



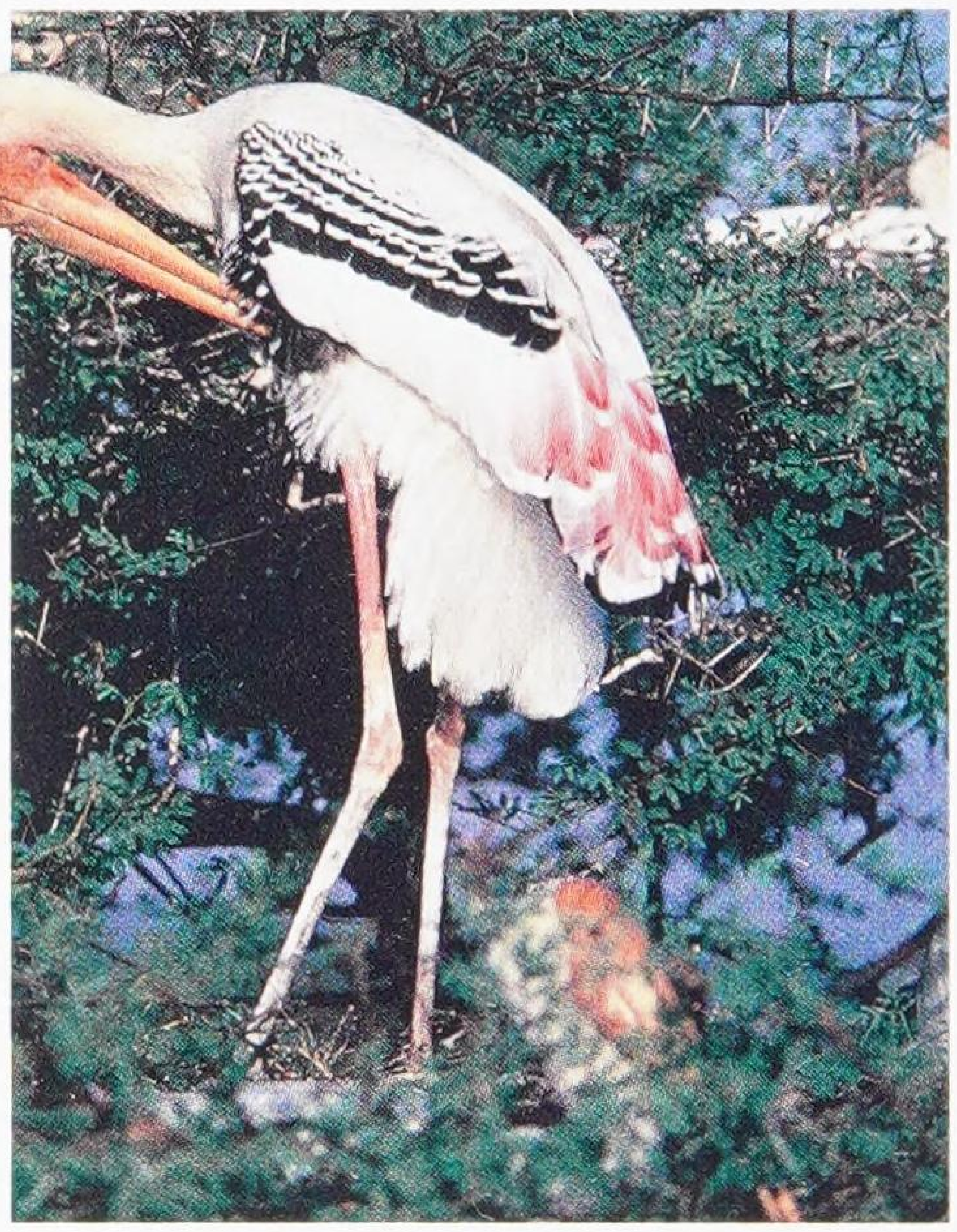


Figure 16-2. Preening conditions feathers and helps make them waterproof.

Figure 16-3. Keen vision allows some birds to locate prey from a long distance.

are hollow with thin cross braces of bone inside for strength and support. The hollow spaces are filled with air. Why do you think it's important for a bird to have a light skeleton?

You can see the skeleton of a bird in Figure 16-4. Notice that the sternum, or breastbone, supports the large chest muscles. The last bones of the spine support the tail feathers, which play an important part in steering and balancing during flight and landing.

Of course, one of the most important adaptations birds have for flight is wings. All birds have wings, even birds that don't fly such as ostriches and penguins. In flying birds, wings are attached to powerful chest muscles. Wings are curved on top and flat or slightly curved on the bottom. The shape gives the bird lift to get off the ground.

Wings also serve important functions for birds that don't fly. Penguins use their wings to swim under water. While running or walking, ostriches and rheas balance with their wings.

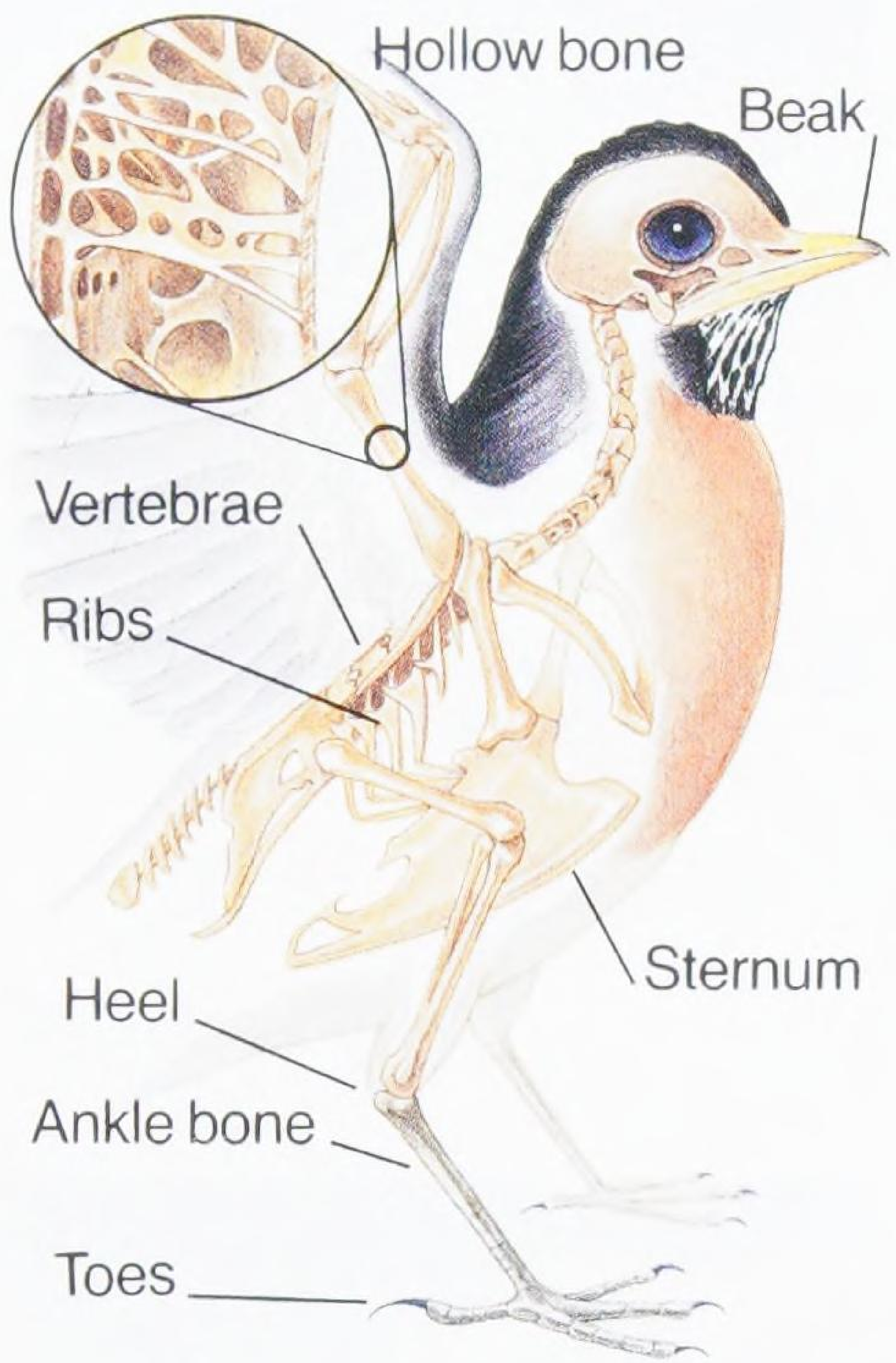


Figure 16-4. The hollow bones of birds are an adaptation for flight.

Connect to...

Physics

Compare how cold-blooded animals and warm-blooded animals maintain body temperatures.

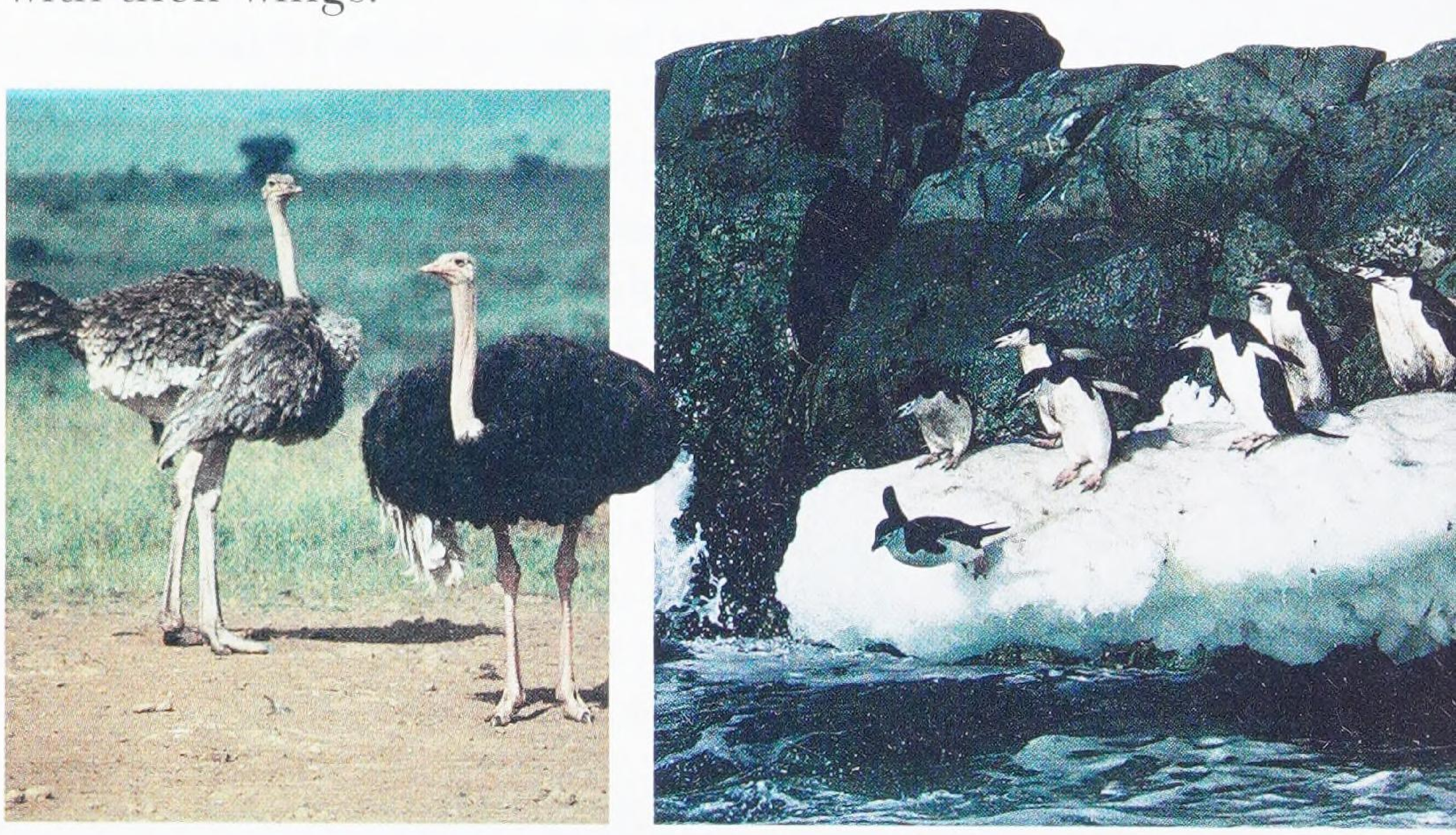


Figure 16-5. Flightless birds use their wings for other purposes. Ostriches (left) use their wings for balance, and penguins (right) use them for swimming.

Digestion and Respiration

Birds get the energy to fly from the food they eat. Because flying requires large amounts of energy, birds need to eat large amounts of food. An efficient digestive system breaks down the food quickly to supply birds with the energy they need. Whereas it takes us as long as a day to digest the food we eat, some birds can digest food in less than an hour.

You learned about part of a bird's digestive process in the Find Out activity at the beginning of this chapter. Food first passes from the mouth into the crop, where it is moistened and stored. From there, it moves into the first part of the stomach, where it is partially digested. Then it moves into the gizzard. Small stones and grit in the gizzard grind and crush seeds and other foods. Food then passes into the small intestine, where the rest of digestion occurs. Finally, nutrients are absorbed by the bloodstream.

Birds also need energy to maintain body temperature. Body heat is generated from the energy in food. Oxygen is needed to convert food to energy. To obtain oxygen, birds have an efficient respiratory system. As you can see in Figure 16-6, birds have two lungs with balloonlike air sacs attached to each one. The air sacs spread into different parts of the body, including the hollow bones. These air sacs increase the amount of oxygen a bird can take in. Having these air sacs spread throughout the body also makes a bird lighter.

Birds have a heart with four chambers. Blood with oxygen is kept separate from blood without oxygen. Blood is circulated very quickly because birds have a rapid heartbeat rate. The hearts of some birds beat almost 1000 times in a minute.

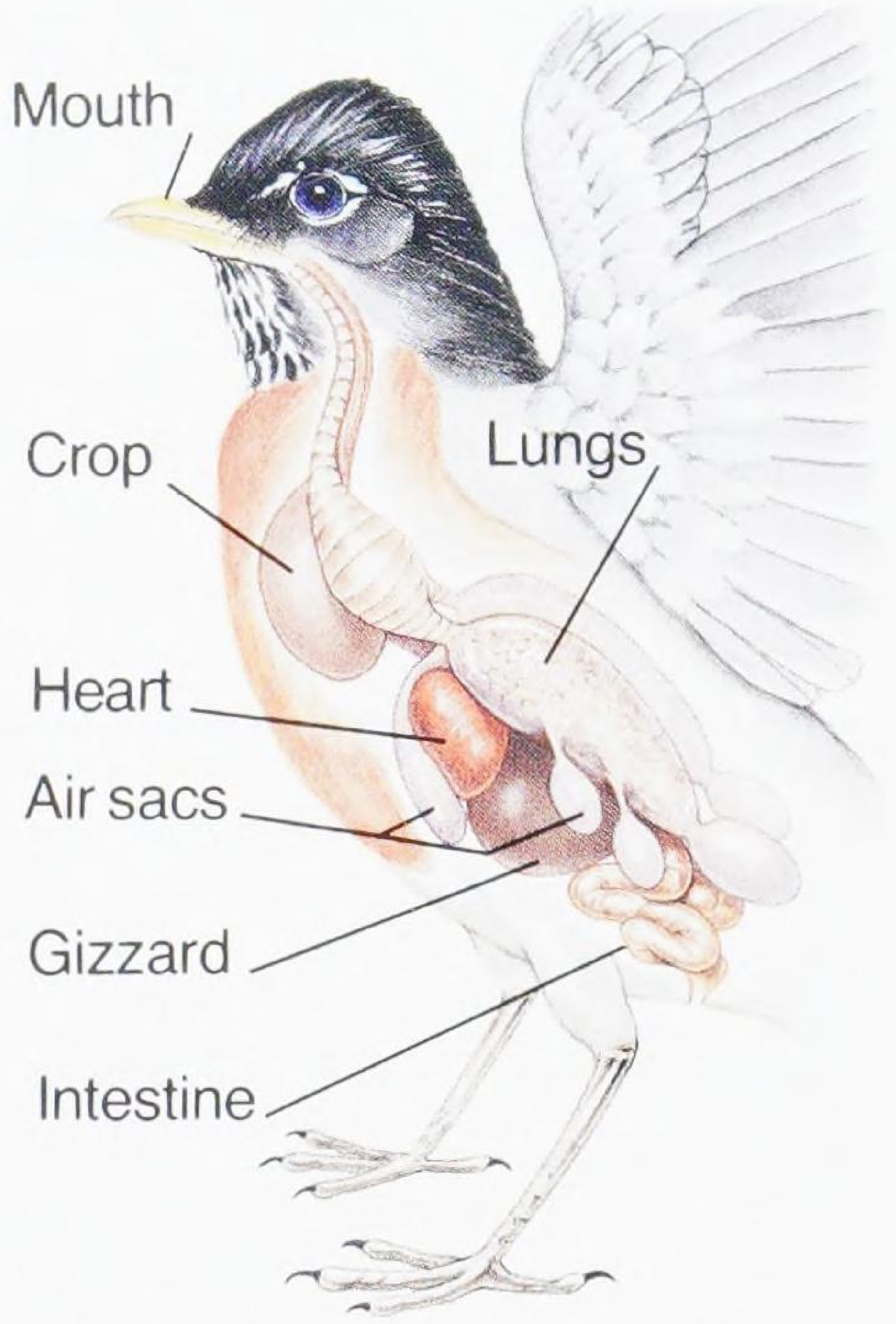


Figure 16-6. A bird's digestive system processes large amounts of food needed for energy. A bird's respiratory system allows a bird to take in large quantities of oxygen.

Reproduction and Development

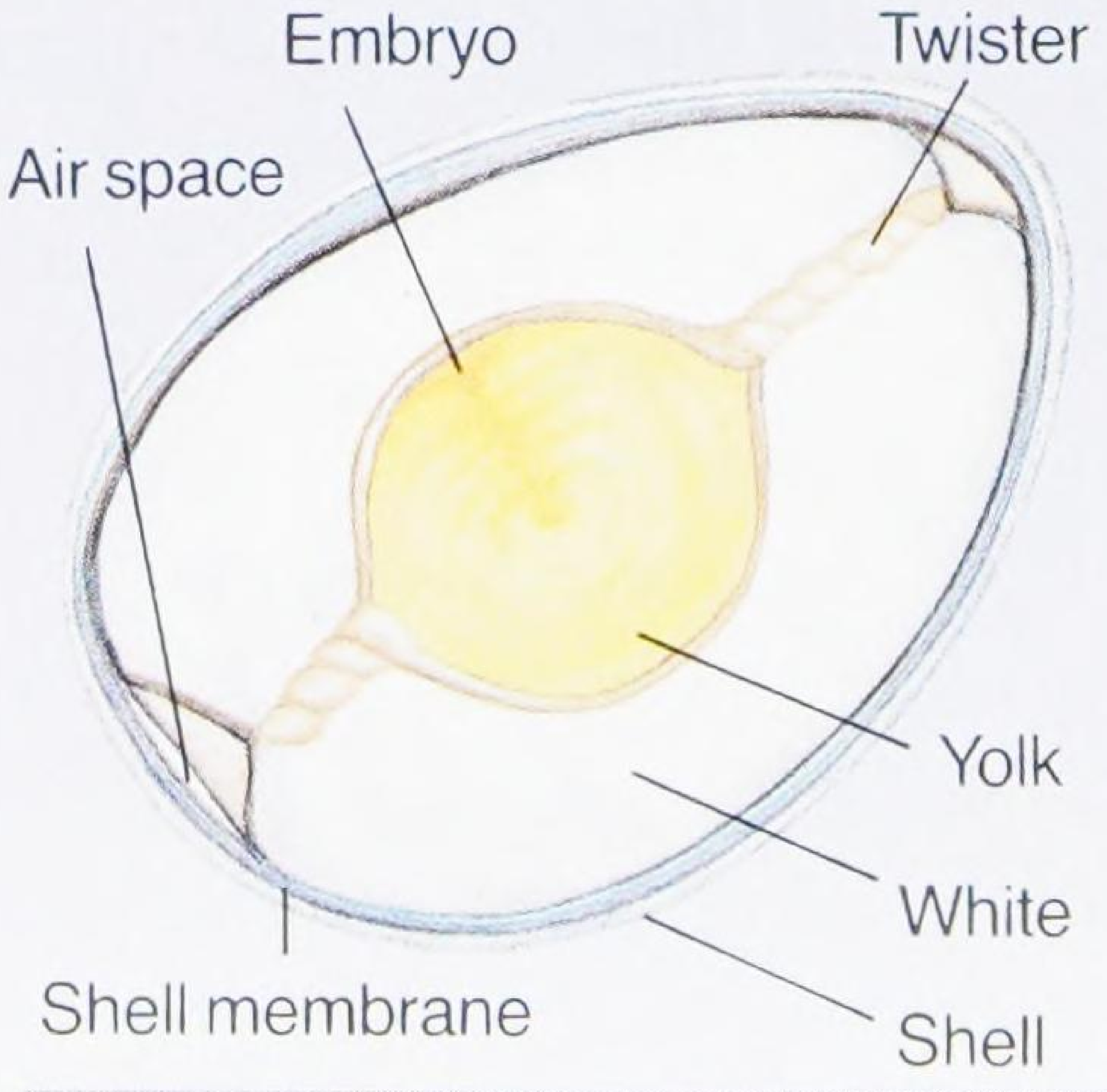
If you've ever cooked scrambled eggs, you are familiar with a bird's egg. Like reptiles, birds reproduce by laying an amniote egg with a shell. Remember that an amniote egg provides a complete environment for a developing embryo. Fertilization is internal, and the shell is formed around the fertilized egg. Bird eggs have the same membranes to protect and nourish the embryo as reptile eggs. Unlike a reptile's egg though, a bird's egg has a hard shell made of calcium carbonate, the same chemical that makes up seashells, limestone, and marble. Birds also usually stay with their eggs to incubate them, and they care for their young.

The female bird usually lays eggs in a nest. Most birds lay from two to eight eggs at one time. All the eggs laid at one time are called a clutch. The length of time the eggs must be incubated varies with the species and the size of the species.

MINI-Lab

What are the parts of a bird's egg?

Open a chicken egg into a shallow bowl. *Observe* the shell and the contents of the egg. *Identify* the parts of the egg from the diagram below. What do you *infer* about the function of each part?



Kinds of Birds

Almost 9000 species of birds belong to the Class Aves. Within this class, birds are classified into orders based on characteristic beaks, feet, feathers, and other physical features. The four most common orders of birds are: the flightless birds, water birds, birds of prey, and perching birds.

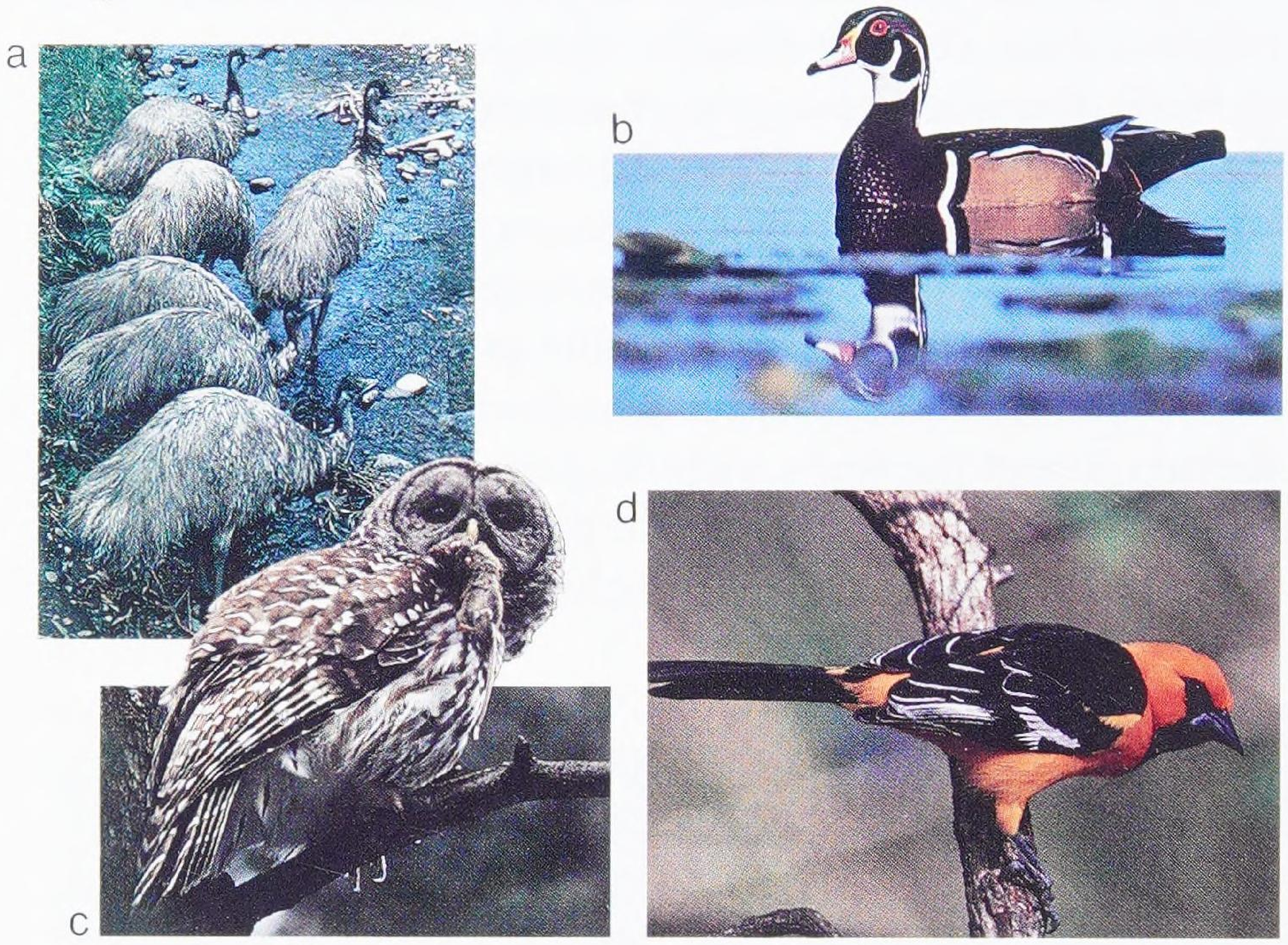


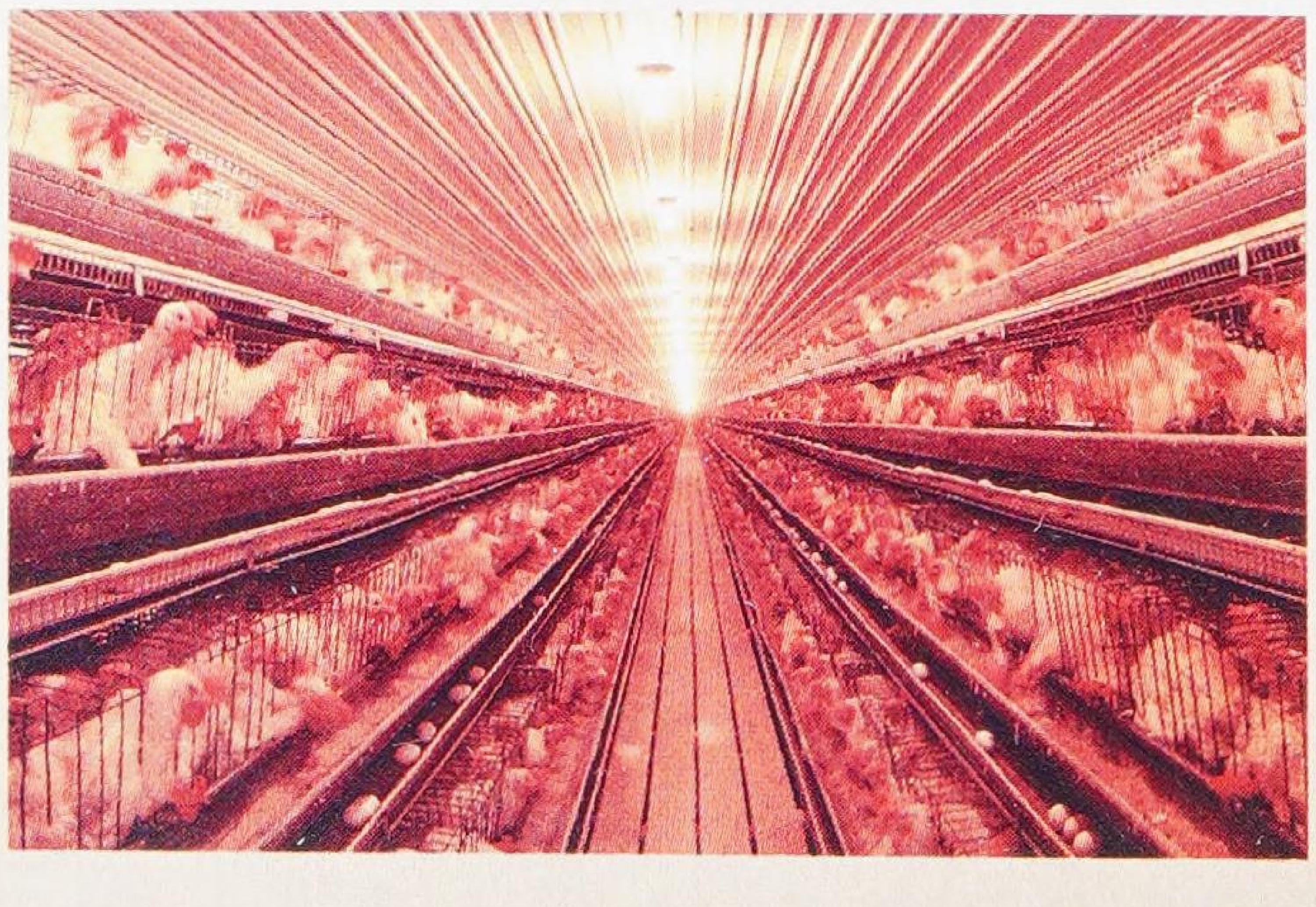
Figure 16-7. The four most common orders of birds are represented by the Emu (a), the Wood duck (b), the Barred Owl (c), and the Altamira oriole (d).

TECHNOLOGY

Healthier Eggs

Scientists and farmers are working to lower the amount of cholesterol in eggs. Two major tactics involve changes in feed and in the hen's environment. One way is to feed hens a diet high in fiber and natural vitamins and minerals. Another way is to use iodine-enriched feed, not to lower egg cholesterol, but to help people who eat the egg to process its cholesterol more quickly. Environmental changes have included removing dust from the air, providing artificial light similar to sunlight, treating water with ultraviolet rays, and reducing electromagnetic radiation from machine motors.

Think Critically: How might changing a chicken's diet lower cholesterol in eggs?



Origin and Importance of Birds

Scientists have learned about the origins of birds by studying their fossils. Feathers and hollow bones decompose easily. As a result, there are few fossils to study. Those that do exist have convinced scientists that birds developed from reptiles millions of years ago. Today, birds still have some characteristics of reptiles, including reptile-like scales on their feet and legs.

The earliest bird fossils belong to the genus *Archaeopteryx* (ar kee AHP tuh rihks). Fossils of *Archaeopteryx* are about 150 million years old. The fossil image in Figure 16-8 shows that almost all the body had feathers. *Archaeopteryx* also had teeth, a reptile-like tail, solid bones, and three claws on each wing. It may have used its claws to climb trees. No one has been able to figure out if it could fly.

Birds play many very important roles in the environment. Birds eat insects and help control insect populations. Birds of prey control populations of rats and mice. Some birds, such as turkey vultures, feed on dead and decaying materials and in return help clean the environment. Hummingbirds pollinate nectar-producing flowers as they feed on the nectar.

In Your JOURNAL

Our endless demand for oil has led to an increased probability of oil spills. **In your Journal,** answer these questions: How do oil spills affect birds? What is being done to prevent these spills?

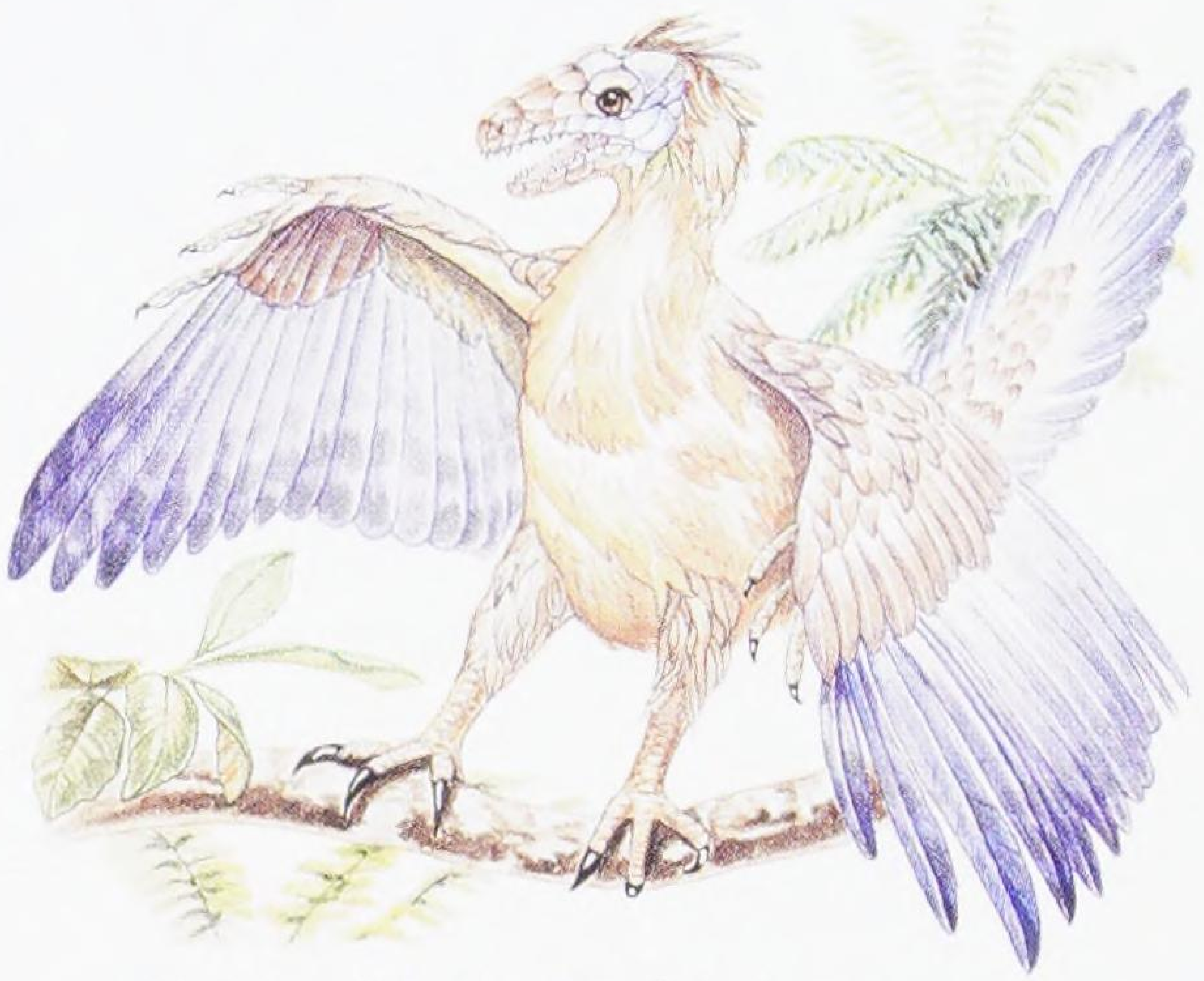


Figure 16-8. *Archaeopteryx* is considered a link between reptiles and birds.

SECTION REVIEW

1. List four characteristics shared by all birds.
2. How are a bird's feathers, air sacs, and skeleton adaptations for flight?
3. Describe reproduction in birds.
4. **Apply:** DDT, a pesticide, was once used extensively to control populations of insect pests such as mosquitoes. Contact with this pesticide caused eagles and other birds to lay eggs with very thin, brittle shells. What do you think was the effect on the populations of these birds? Explain.
5. **Connect to Physics:** Find out how the shape of a bird's wings enables the bird to fly.

Skill Builder

Comparing and Contrasting

Using the photographs in this chapter, compare and contrast the beaks and feet of flightless birds, water birds, birds of prey, and perching birds. If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.

ACTIVITY 16-1

Observing Contour and Down Feathers

Problem: *What is the structure of contour and down feathers?*

Materials

- contour feather
- down feather
- hand lens
- scissors
- balance

Procedure

1. Use a hand lens to examine a contour feather. Find the shaft, vanes, and barbs. Use Figure 16-2 on page 373 for help.
2. Hold the shaft by the thicker end and carefully bend the opposite end. *Observe* what happens when you release the bent end.
3. With the scissors, cut about 2 cm from the end of the shaft. Examine the cut end with the hand lens.
4. Separate the barbs near the center of the vanes. Use your fingers and gently rub the feather where you separated it. *Observe* what happens.
5. Draw the feather and label the shaft, vanes, and barbs.
6. Use a hand lens to observe a down feather.
7. Draw and label the structure of a down feather.
8. Use a balance to find out how many contour feathers it takes to make 1 g.

Data and Observations

Contour Feather	Down Feather

Analyze

1. What happens when you release the bent end of the contour feather?
2. Describe how the cut end of the shaft appears.
3. What happens to the separated barbs when you rub them with your fingers?
4. How many feathers were in 1 g?

Conclude and Apply

5. *Compare* the shape, filaments (barbs), and shaft of the down feather with those of the contour feather.
6. *Infer* how the structure of a contour feather is adapted for flight.
7. *Infer* how the structure of a down feather is adapted for insulation.

Adelie Penguins, Antarctica

Mammals

16-2

Objectives

- Identify the characteristics of mammals and explain how they enable mammals to adapt to different environments.
- Distinguish among monotremes, marsupials, and placental mammals.
- Compare reproduction and development in the three kinds of mammals.

New Science Words

mammals
mammary glands
herbivores
carnivores
omnivores
placental mammals
gestation period
placenta
umbilical cord
marsupials
monotremes

Characteristics of Mammals

Cats, whales, moles, bats, horses, and people are all mammals. Mammals live almost everywhere, from tropical and arctic regions, to deserts, woodlands, and oceans. You may be wondering what you, a mole, and a whale have in common. Each species of mammal is adapted to its way of life, but all mammals share some characteristics. **Mammals** are warm-blooded vertebrates that have hair and produce milk to feed their young.

Nearly all mammals have hair on their bodies at some time during their lives. Many have thick fur that covers all or parts of their bodies to keep them warm. Others, such as whales and dolphins, have little hair. However, they do have a thick layer of fat that helps keep them warm. Elephants and rhinoceroses have little hair, but they live in warm climates. Porcupine quills and the spines of a hedgehog are modified hairs that protect them from their enemies. Sensory hairs, called whiskers, around the mouth of many mammals, such as cats, mice, and sea otters, help them keep in touch with their environment.

Skin covers and protects the bodies of all mammals. Hair, horns, claws, nails, and hooves are produced by the skin. The skin contains many different kinds of glands. **Mammary glands,** which are characteristic of all mammals, produce the milk female mammals use to feed their young. Oil glands produce oil to lubricate and condition the hair and skin, and sweat glands help mammals stay cool. Many mammals have scent glands that are used for self-defense and to recognize members of their own species.

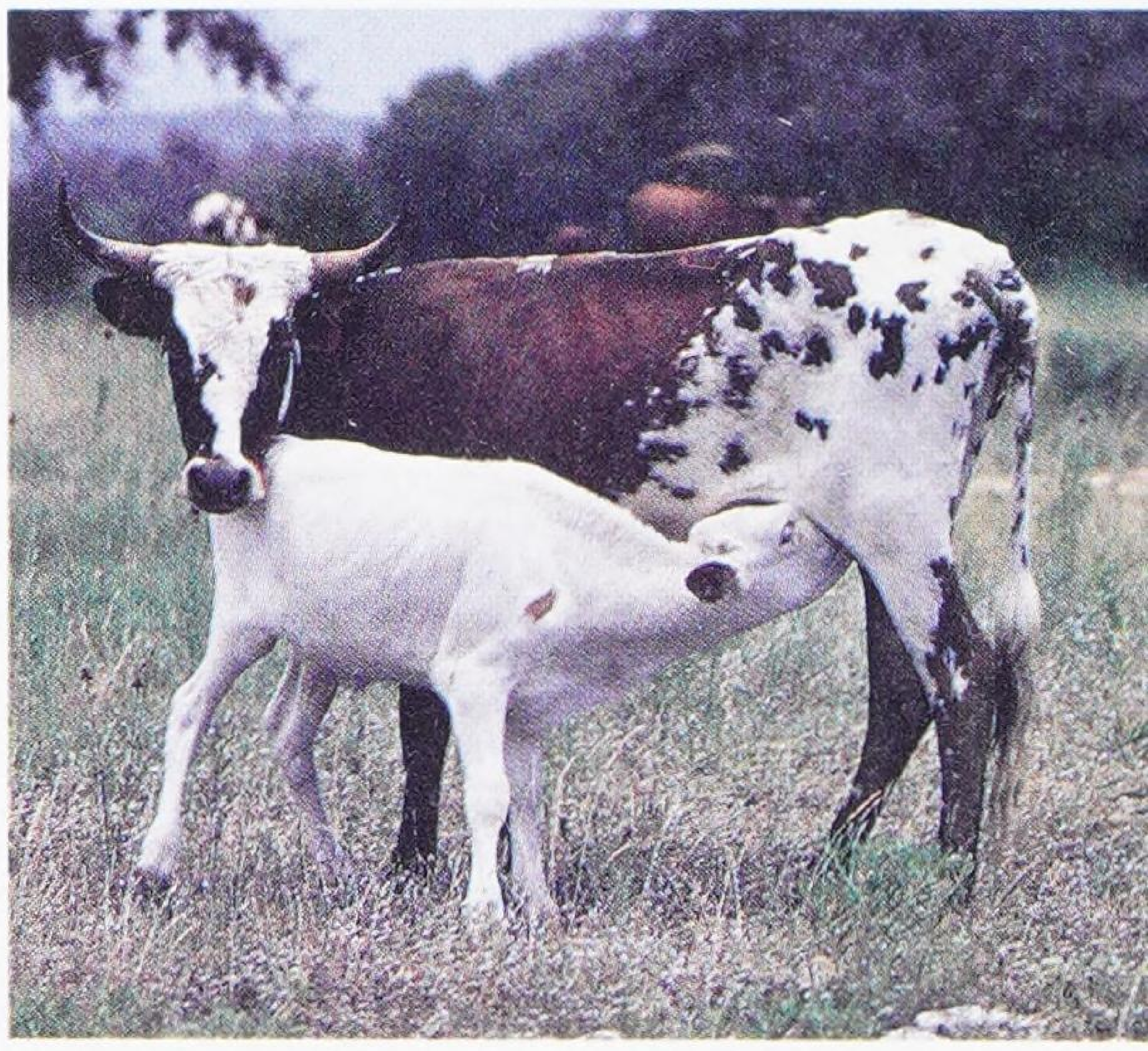


Figure 16-9. Mammals care for their young after they are born. Mammary glands in the female secrete milk to feed the young.

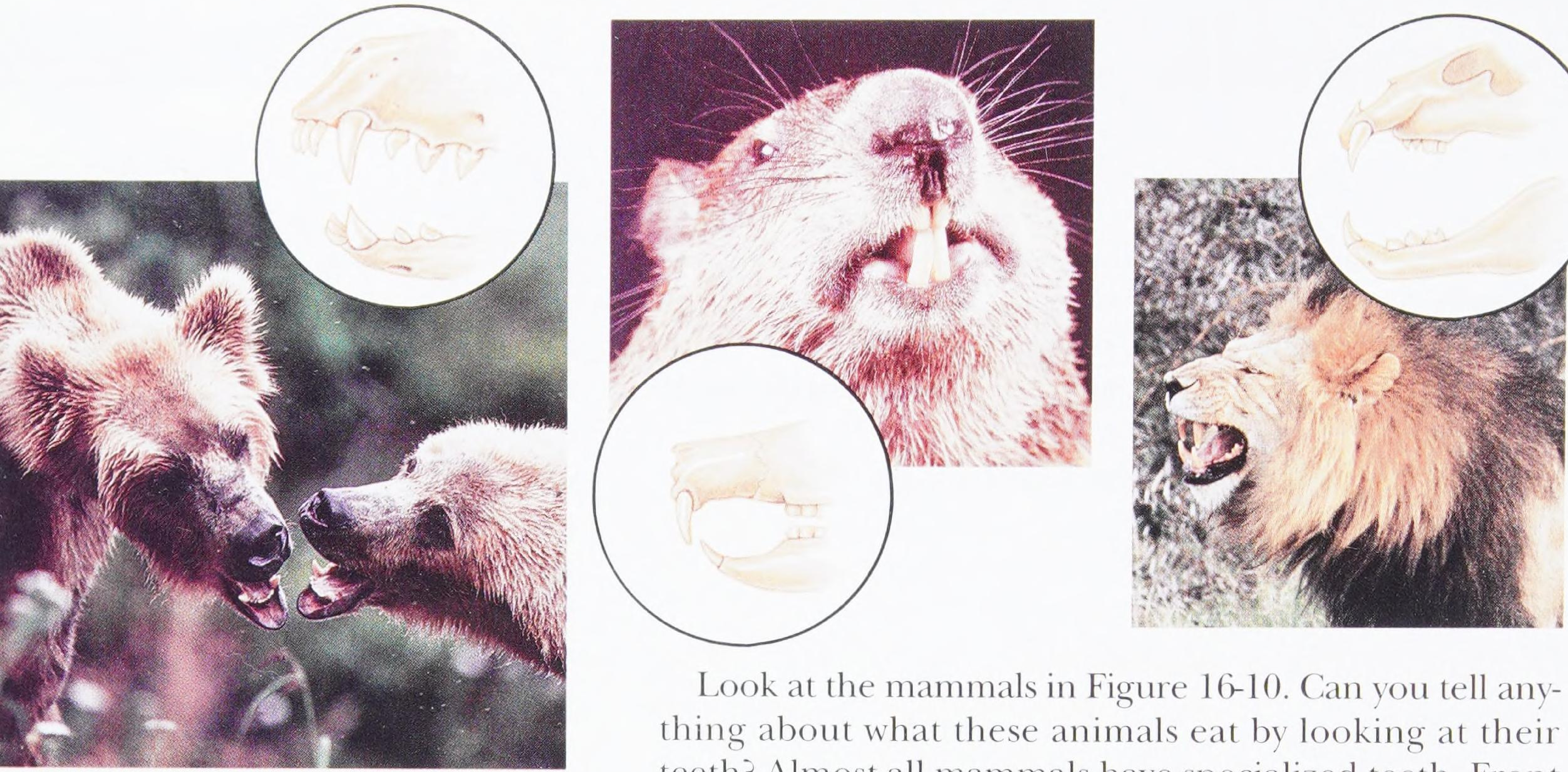


Figure 16-10. Mammals have teeth specialized for the food they eat.

Look at the mammals in Figure 16-10. Can you tell anything about what these animals eat by looking at their teeth? Almost all mammals have specialized teeth. Front teeth, called incisors, bite and cut. Next to the incisors, pointed canine teeth grip and tear. Premolars and molars shred, grind, and crush. Rabbits use their large incisors to cut off blades of grass. Animals like the rabbit that eat plants are called **herbivores.** Many mammals are herbivores. **Carnivores,** such as tigers, are flesh-eating animals. Some animals, like yourself, eat both plants and animals and are called **omnivores.**

Mammals live very active lives. Think of all the things you do each day! The body systems of mammals allow them to be very active and to adapt to many environments. All mammals have a four-chambered heart and a network of blood vessels. This type of heart allows blood coming from the lungs, full of oxygen, to be pumped directly to the body. Mammals have well-developed lungs made up of millions of microscopic sacs that increase the surface area for exchange of carbon dioxide and oxygen.

The digestive system of mammals varies according to the kind of food the animal eats. Carnivores have a short digestive system compared to that of herbivores. Meat is more easily digested than plant material. Herbivores need a long digestive system to help them break down the carbohydrate called cellulose found in plants.

The nervous system is made up of a brain, spinal cord, and nerves. The brain in most mammals is larger than those of other animals the same size. Mammals are able to learn and remember more than other animals.

MINI-Lab

What are the characteristics of hair?

Brush or comb your hair to remove a few loose hairs. Take two hairs from your brush that look like they still have the root attached. Make a wet mount slide of the two hairs being sure to include the root. Focus on the hairs with the low power objective. Draw what you see. Switch to the high power objective and focus on the hairs. Draw what you see. *Describe* the characteristics of the hair and root.

Reproduction and Development

All mammals reproduce sexually. Most mammals give birth to live young after a period of development inside a uterus. One or both parents care for the young after they are born.

Mammals are classified into three groups based on how the young develop. The three groups are: placental mammals, marsupials, and monotremes.

In **placental mammals,** embryos develop inside the female in an organ called the uterus. The time during which the embryo develops in the uterus is called the **gestation period.** Gestation periods range from 16 days in hamsters to 650 days in elephants. Placental mammals are named for the **placenta,** an organ developed by the growing embryo that attaches to the uterus. An **umbilical cord** attaches the embryo to the placenta. Several blood vessels make up the umbilical cord. The placenta absorbs oxygen and food from the mother's blood. The umbilical cord transports the food and oxygen to the embryo. The mother's blood never mixes with the blood of the embryo.

The kangaroo in Figure 16-12 is an example of a marsupial. **Marsupials** are pouched mammals that give birth to tiny, immature offspring. Young kangaroos are born only a few days after fertilization takes place and are about the size of a honeybee at birth. Immediately after birth, the young kangaroo crawls into the pouch on the female's abdomen and attaches to a nipple. It remains protected in the pouch while it develops more completely. After a few months, the young kangaroo, called a joey, is better developed and crawls out of the pouch. The joey returns to its mother's pouch for protection.

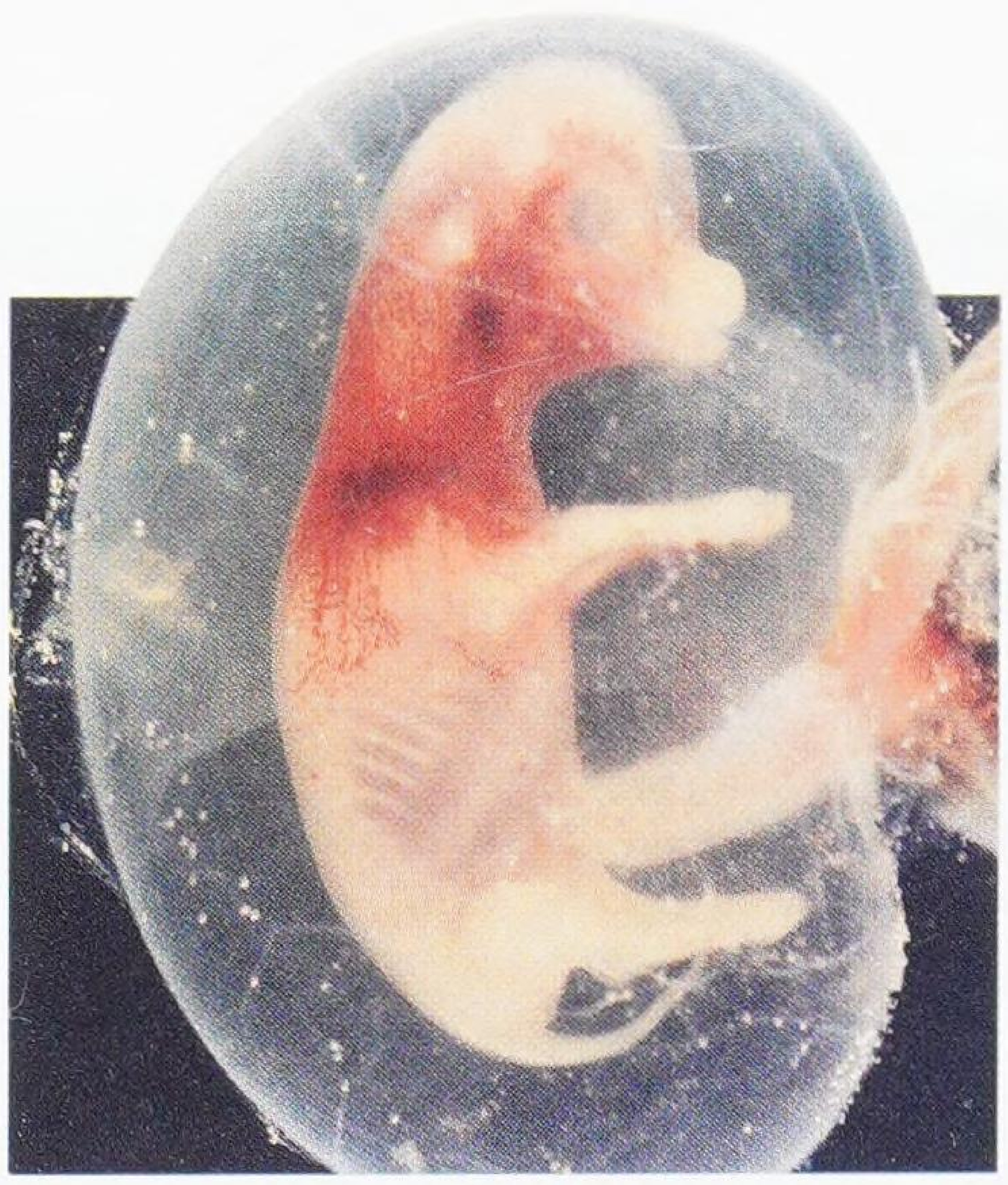
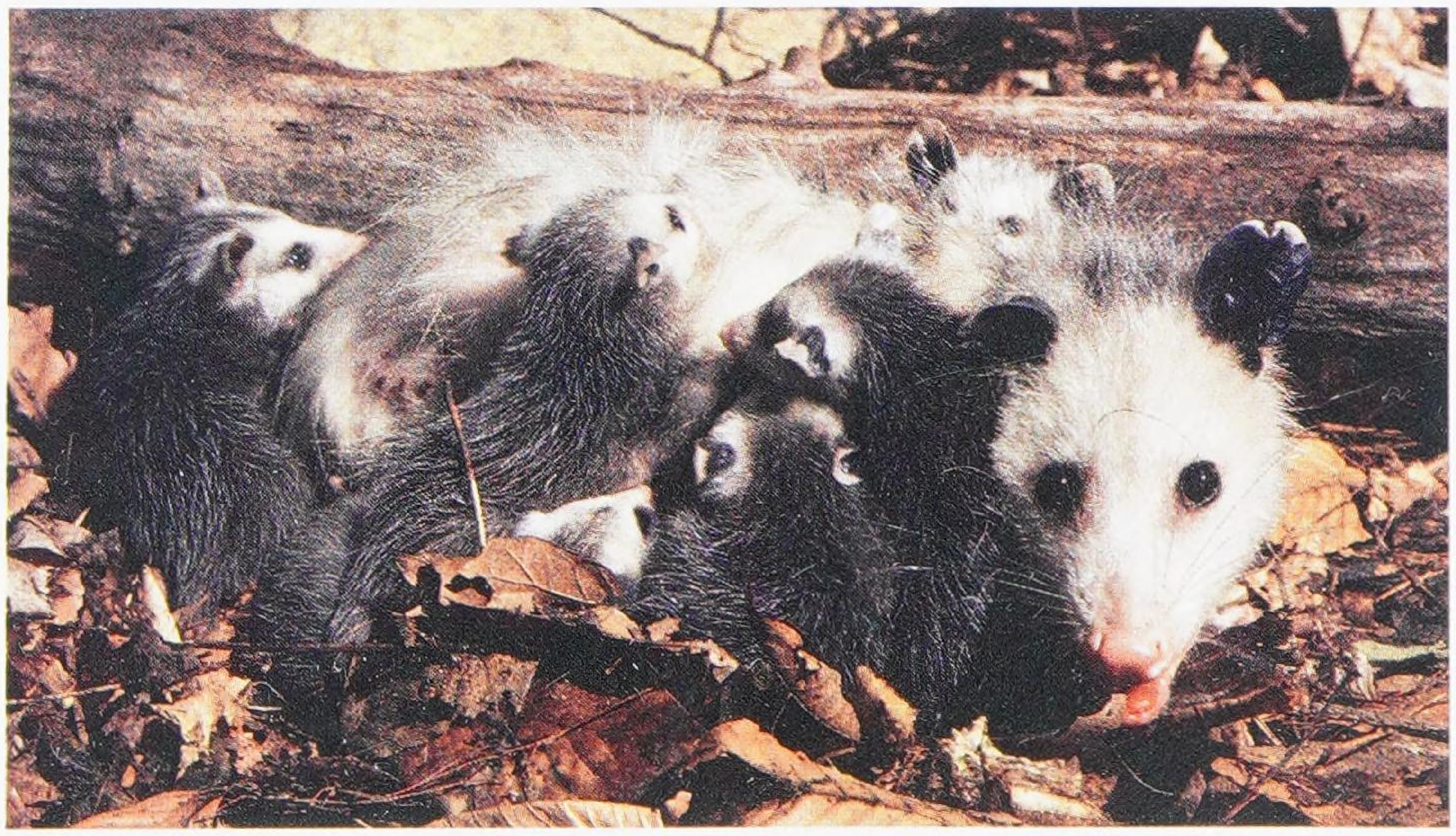


Figure 16-11. A mammal embryo develops inside a sac of fluid inside the uterus of a female.

Figure 16-12. Marsupials carry their developing young in a pouch outside their bodies. A kangaroo and baby (right) and an opossum with babies (left) are marsupials.



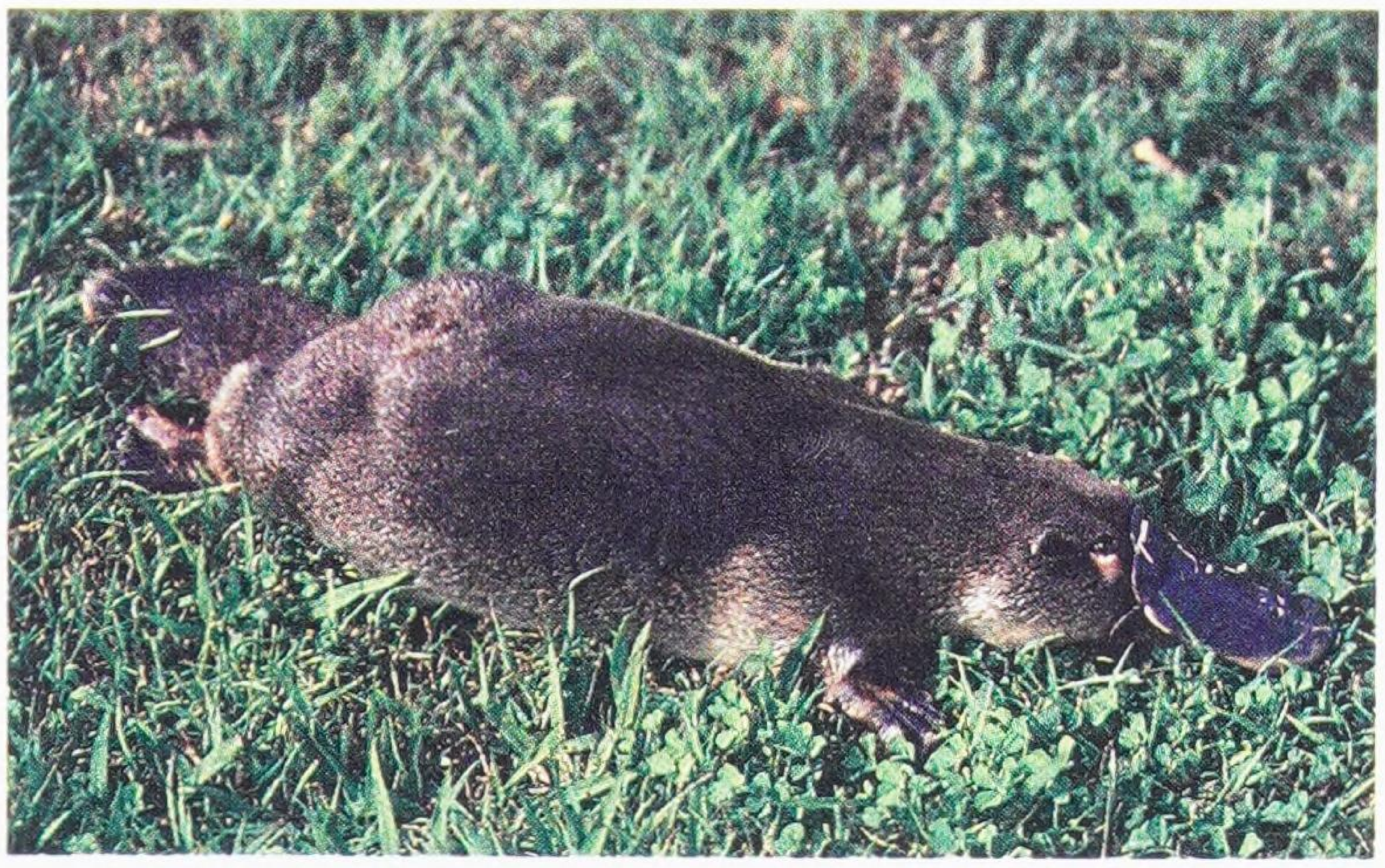


Figure 16-13. A duckbilled platypus is a monotreme. Monotremes are mammals that lay eggs.

The marsupials you are probably the most familiar with are kangaroos and opossums. Opossums are the only marsupials native to North America. Other marsupials are the koala, Tasmanian devil, and wallaby. Marsupials live primarily in Australia, Tasmania, and New Guinea.

Monotremes do not give birth to live young as placental mammals and marsupials do. Duckbilled platypuses are the most well-known monotreme. **Monotremes** are mammals that lay eggs with tough, leathery shells. The female incubates the eggs. Mammary glands of the monotremes do not have nipples. When the young hatch, they nurse by licking milk from the skin and hair surrounding the female's mammary glands.

Most placental mammals, as well as all marsupials and monotremes, are nearly helpless, and sometimes even blind, when they are born. They can't do much for themselves the first several days or even months. They just eat, sleep, and develop.

Connect to... Physics

Echolocation is used in sonar and by some animals. High frequency sound waves are given off and bounce off objects. Some bats are capable of echolocation. In what way is this behavior an advantage for the bat in obtaining food?

Mammal parents are very protective. They make homes in which their young can grow protected from predators and the weather. For some, such as bears and foxes, home is an underground burrow called a den. For chimpanzees and squirrels, home is a nest in the top of a tree. The young of some mammals, such as antelope, deer, elephants, whales, and dolphins, must be well developed at birth to be able to move with their constantly moving parents. Those that live on land can usually stand by the time they are a few minutes old. Marine mammals can swim as soon as they are born.

During the nursing period, young mammals learn skills they need to survive. Among most kinds of mammals, the mother raises the young alone. In some species, males help with nest building, finding food, and protecting the young.

Kinds of Mammals

There are 18 orders of modern mammals. Monotremes and marsupials make up one order each. Placental mammals make up the other orders. Each order has adaptations that help identify it. Characteristics and examples of several of the most common orders and examples are given in Table 16-1.

Table 16-1

MAJOR ORDERS OF PLACENTAL MAMMALS

Chiropterans
Bats
Front limbs adapted for flying; feed on fruit, insects or blood; active at night

Rodents
Mice, rats, squirrels and beavers
Pair of greatly enlarged incisors on upper and lower jaws; specialization for movements such as gliding, swimming, leaping, hopping, and running

Lagomorphs
Rabbits, hares, and pikas
Two pairs of upper incisors; bodies covered with soft fur; long legs adapted to jumping and running

Cetaceans
Whales, dolphins, and porpoises
Forelimbs are modified into flippers; breathe through one or two blowholes on top of their heads; little or no hair; largest animals on Earth

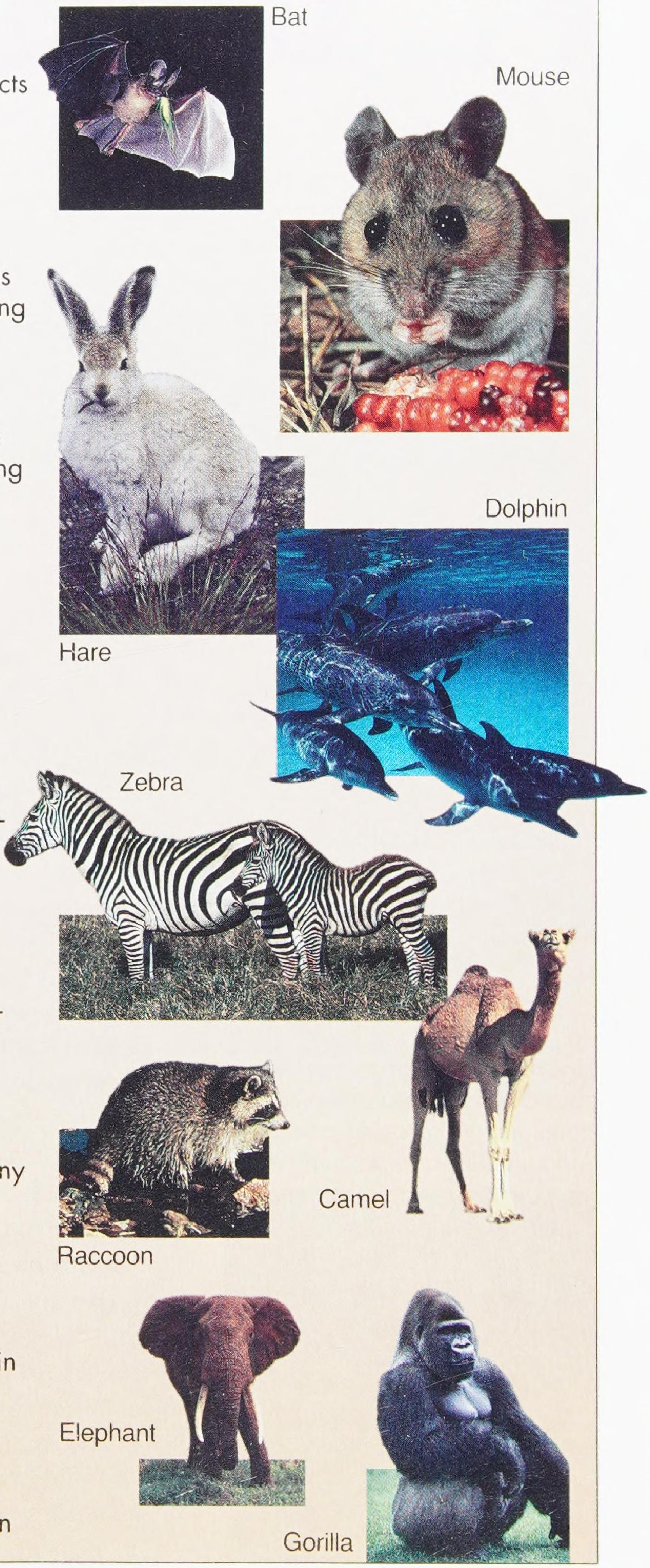
Perissodactyls
Horses, zebras, and rhinoceroses
Hooves made of a hard protein; odd number of toes; flat, grinding molars; large skeletons adapted for running

Artiodactyls
Deer, moose, camels, pigs, and cows
Hooves made of a protein called keratin; even number of toes; large, flat molars; complex stomachs and intestines

Carnivores
Cats, dogs, bears, and racoons
Long, sharp canine teeth; long, sharp claws; many hunt and kill prey

Proboscideans
Elephants
Elongated nose forms a trunk to eat and drink; pair of enlarged incisors forms tusks; leathery skin

Primates
Humans, apes, and monkeys
Long arms with grasping hands and five fingers; opposable thumb; eyes face forward; large brain



PROBLEM SOLVING

What Colors Can Spot See?

What colors can dogs see? Most people believe that dogs are color-blind and see the world in black and white.

In 1969, scientists performed some experiments to determine if dogs were color-blind. The experiments indicated that dogs respond to color. But, because the experiments did not test whether the dogs were responding to color or differences in brightness, many scientists still believed dogs were color-blind.

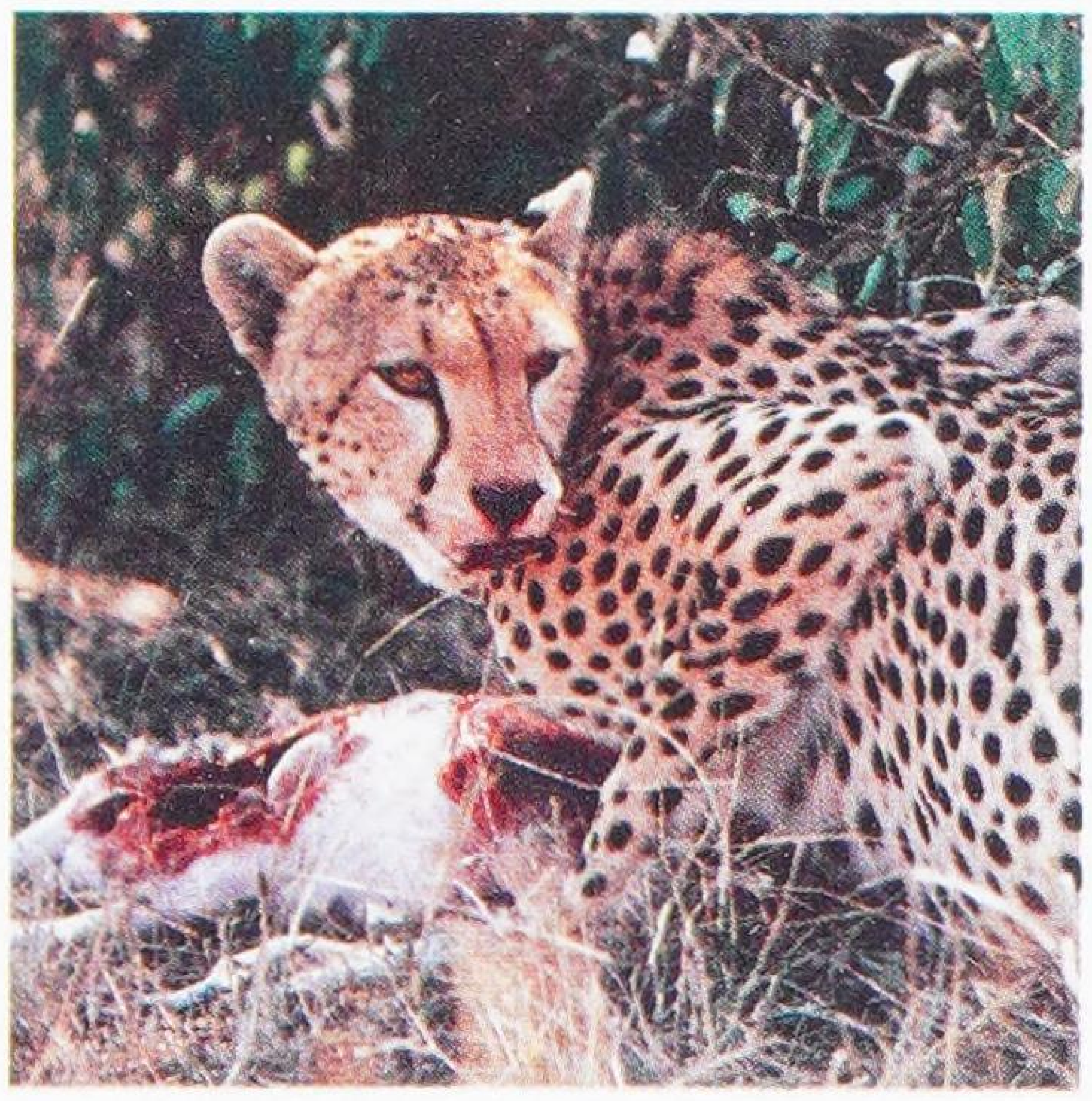
A recent study indicates that dogs are not color-blind. The dogs in the experiments could tell the difference between white light and colored light and between colors at the opposite ends of the spectrum. The scientists were careful to control differences in brightness. Based on their investigation, the scientists speculate that dogs can see blues, but they see greens, yellows, oranges, and reds as one shade.

Think Critically: Compare and contrast the 1969 experiment with the more recent investigation.

Origin and Importance of Mammals

About 65 million years ago, dinosaurs became extinct. This opened up new habitats for mammals, and they began to branch out into many different species. Eventually, they became the most numerous animals on Earth. Some species died out, but others gave rise to modern mammals. Today, more than 4000 species of mammals have evolved from tiny, shrewlike creatures that lived 200 million years ago.

Figure 16-14. Large carnivores such as this cheetah help control populations of grazing animals in Africa, India, and parts of Asia.



Mammals are very important in maintaining a balance in the environment. Large carnivores such as lions help control populations of grazing animals. Bats help pollinate flowers, and some pick up plant seeds in their fur and distribute them.

Mammals are in trouble today. As millions of acres of wildlife habitat are developed for shopping centers, recreational areas, and housing, many mammals are left without food, shelter, and space to survive.

Overhunting has threatened many mammal populations in the past, but most countries now have strict hunting regulations. However, these regulations don't keep people from killing and capturing wild mammals to sell. People use poisons to kill many mammals such as rats, prairie dogs, and rodents. Insect-eating mammals are affected by insecticides. Because of these problems, many people are working hard to protect mammals. You will learn more about measures being taken to protect endangered mammals and other species in Chapter 28.

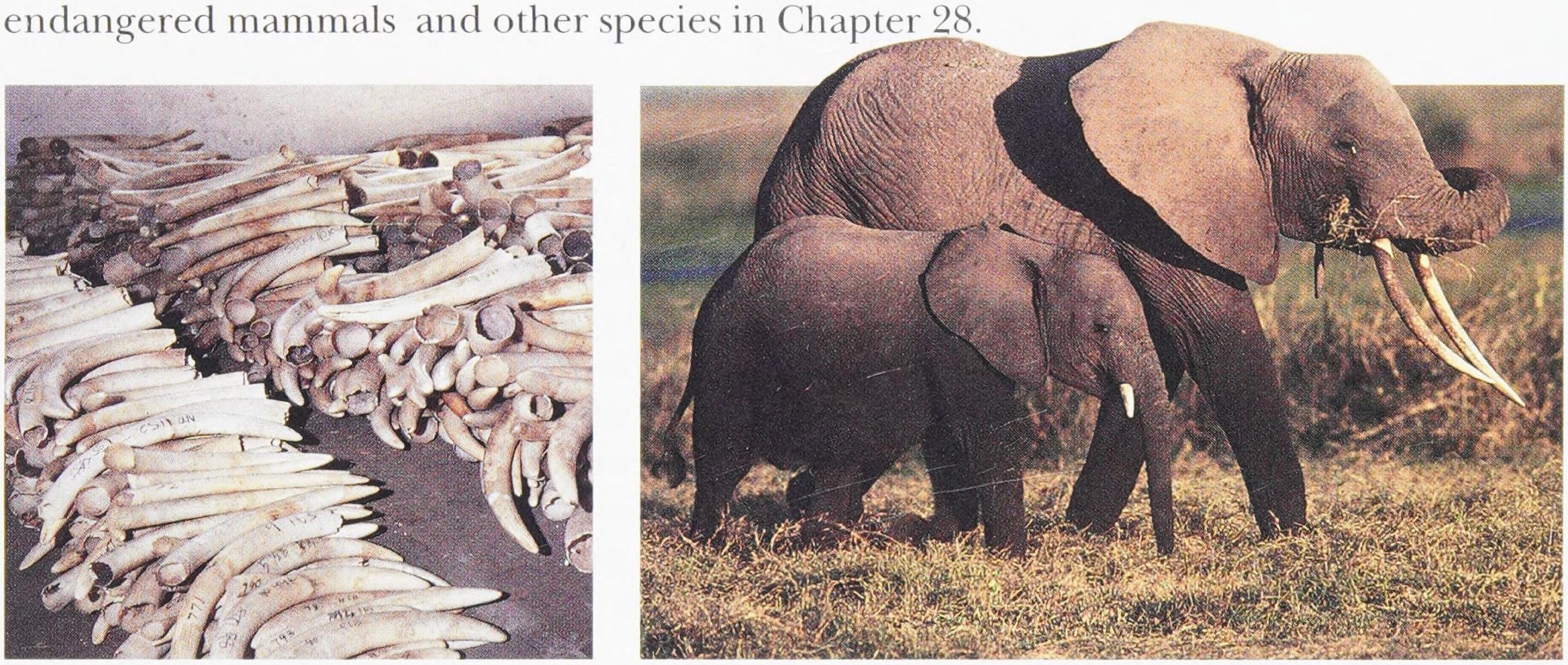


Figure 16-15. Many elephants have been killed for their ivory tusks.

SECTION REVIEW

1. Describe five characteristics of all mammals.
2. Differentiate among placental mammals, monotremes, and marsupials.
3. Give examples of six orders of mammals, and briefly list characteristics of each.
4. **Apply:** Suggest a reason why placental mammals are far more numerous than monotremes and marsupials.
5. **Connect to Physics:** Find out what evaporation is and how it benefits warm-blooded animals.

Classifying

Skill Builder

Using Table 16-1, classify the following mammals into three groups: whales, echidnas, koalas, horses, elephants, opossums, kangaroos, rabbits, bats, bears, platypuses, monkeys. Compare and contrast their characteristics. If you need help, refer to Classifying in the **Skill Handbook** on page 680.

SCIENCE & SOCIETY

16-3 Saving the Manatee

New Science Words

manatees
poaching

Objectives

- Identify the characteristics of manatees.
- Explain the major threats to manatees today.

"Sea Cows"?!

Have you ever thought about running into a cow in the water? Unless you live in Florida, you probably didn't realize that "sea cows" exist. Sea cows, or **manatees,** are large mammals belonging to the order Sirenia that live in salt waters. Adults weigh about half a ton. They are known to live in the rivers, estuaries, and coasts in the tropical and subtropical regions. They cannot tolerate cold temperatures.

Unfortunately, manatees are now on the endangered species list. The slow, curious "sea cows" are not afraid to approach and investigate visiting humans, making them very easy to hunt. In the past, they were heavily hunted for their meat, oil, and hides.

Today, manatees are still dying. Manatees are in danger from barges and motorboats. They often collide with these boats and are injured or cut by propellers. In fact, collisions are so common with manatees that researchers are able to identify more than 900 individual manatees just by using their distinctive scars caused by these collisions. Manatees are herbivores and feed on aquatic plants that clog waterways. Many manatees have been poisoned by herbicides used to kill these plants.

Connect to... Earth Science

Dinosaurs became extinct by the Cenozoic Era, when mammals and flowering plants began to flourish. **In your Journal,** write an opinion about whether strong measures should be taken to prevent extinction of species when it is known that they are endangered.

The Future of Manatees

Researchers are very concerned about the future of these huge, quiet mammals. Although the United States protected them by law in 1983, the state of Florida cannot employ enough law enforcers to prevent illegal hunting called **poaching.** In 1988, 133 manatees were killed in Florida. By 1989 only about 1200 manatees were believed to be living in United States waters.

Manatees have a very slow rate of reproduction. Manatees that are killed by accident are not quickly replaced. Combine this steady decrease in population with the loss of habitat due to development (nearly 1000 people move to Florida each year) and extinction does not look to be very far away.

What can be done to save the manatees? Some suggest developing more refuges where boats would not be allowed to travel. Because Florida real estate is very valuable, this is not likely to be popular with coastal landowners. Another option is to enforce a slower speed limit on the boats that travel in the Intracoastal Waterway where many manatees are injured.

Whatever the solution, manatees need more protection soon if we hope to save them from their current fate of extinction.

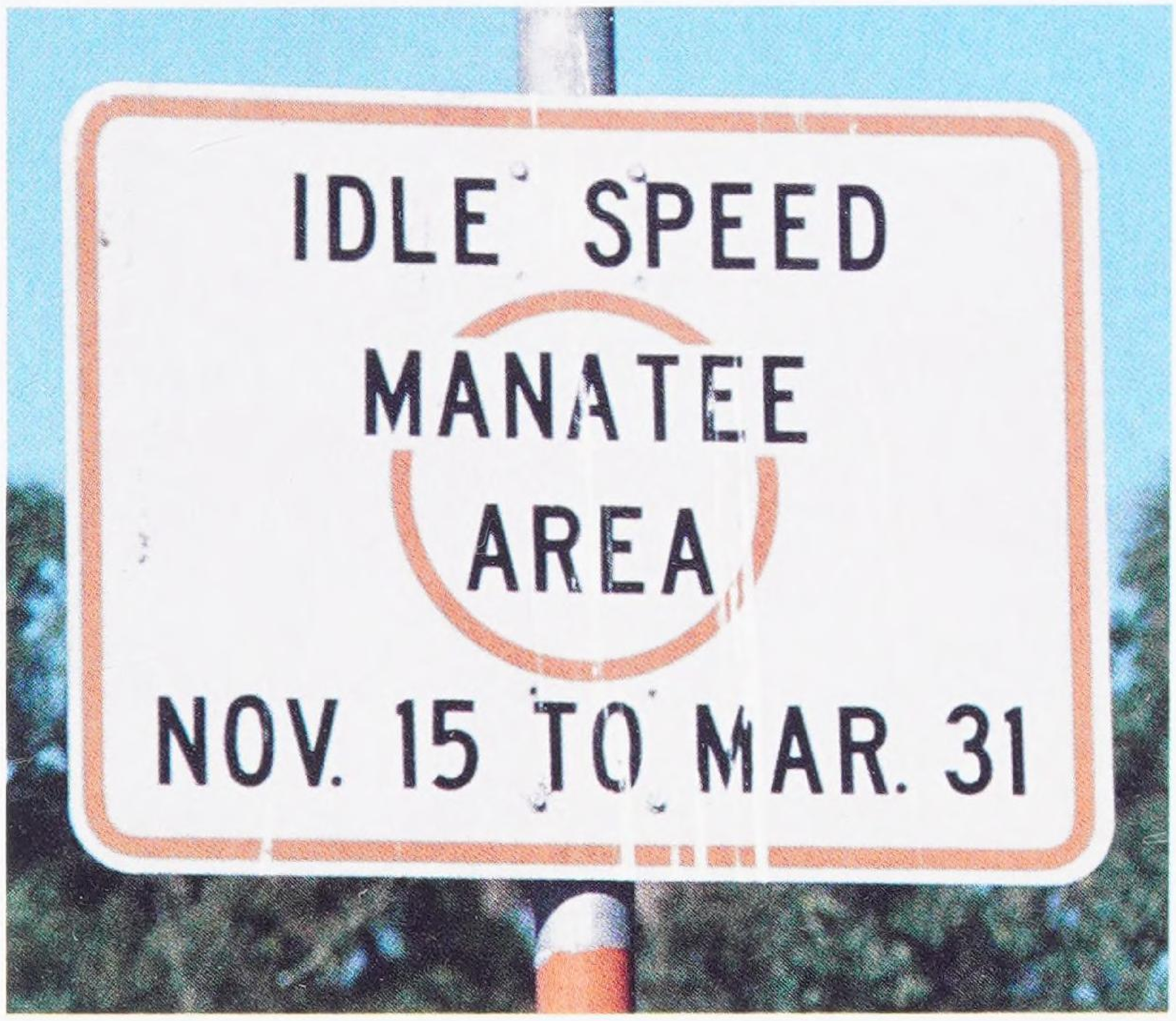


Figure 16-16. Warning signs are being placed in areas where manatees are found to help protect them from being injured.

SECTION REVIEW

1. What are manatees and where do they live?
2. What two major factors account for the gradual decrease in the population?
3. **Connect to Earth Science:** Find out when large mammals such as the wooly mammoth and saber-tooth tiger became extinct. Hypothesize what could have caused their extinction.

You Decide!

SCIENCE & SOCIETY

In Miami, Florida, injured manatees are taken by a special ambulance to Miami's Seaquarium where they can be treated. Scientists are hoping to release the treated manatees and help the population become more stable. The estimated cost of treatment for one injured manatee is about $18 000. When returned to its environment, there is no guarantee that it will escape another, perhaps fatal, injury. Some people believe that it's not right to spend this much money on saving the manatees. What do you think?

ACTIVITY 16-2
Classifying Vertebrates

Problem: *How do scientists classify vertebrates?*

Materials
- paper
- pencil
- animals or pictures of animals

Procedure
1. Copy the four-column chart shown under Data and Observations.
2. Write the name of each animal you are studying in the first column.
3. *Predict* the class of the animal and write the predicted class in the second column.
4. Write the characteristics of the animal that helped you decide its class.
5. Use the key to find the class of each animal. Write the class name in the last column.

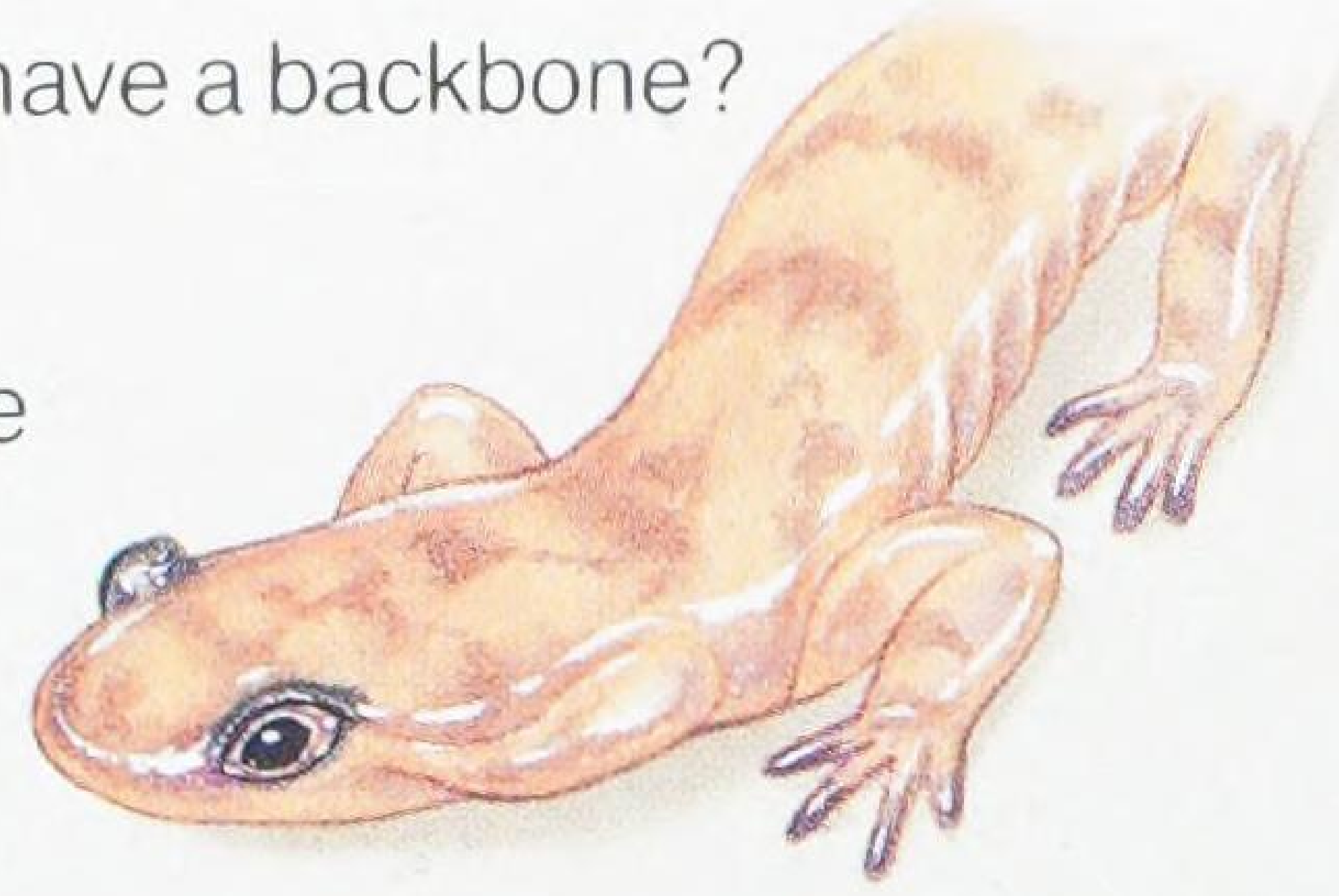
Data and Observations

Animal	Predicted class	Characteristics	Actual class

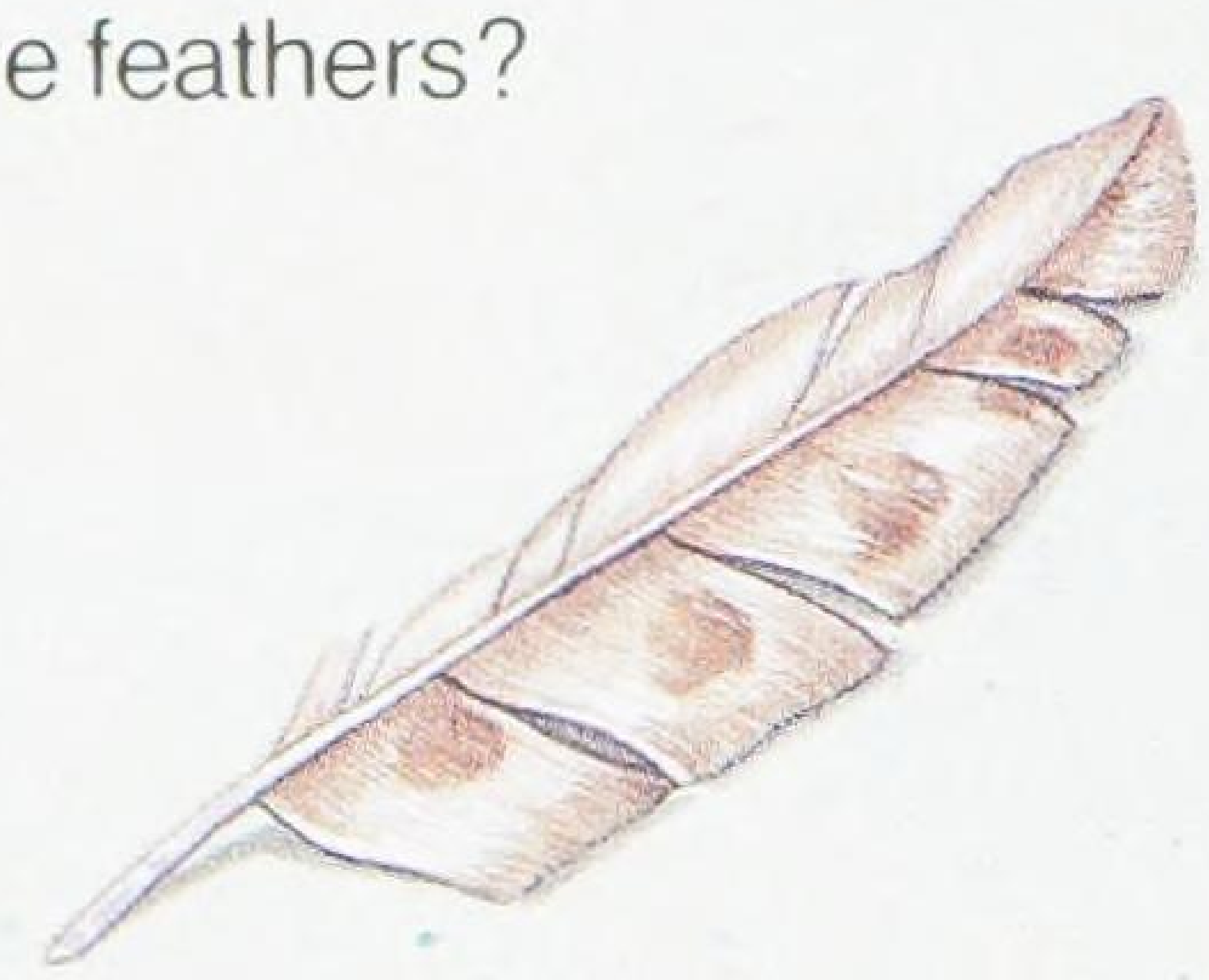
Analyze
1. How many of your predictions were correct?
2. What characteristics of each vertebrate class are used to *identify* the animals?

Conclude and Apply
3. How do scientists classify vertebrates?

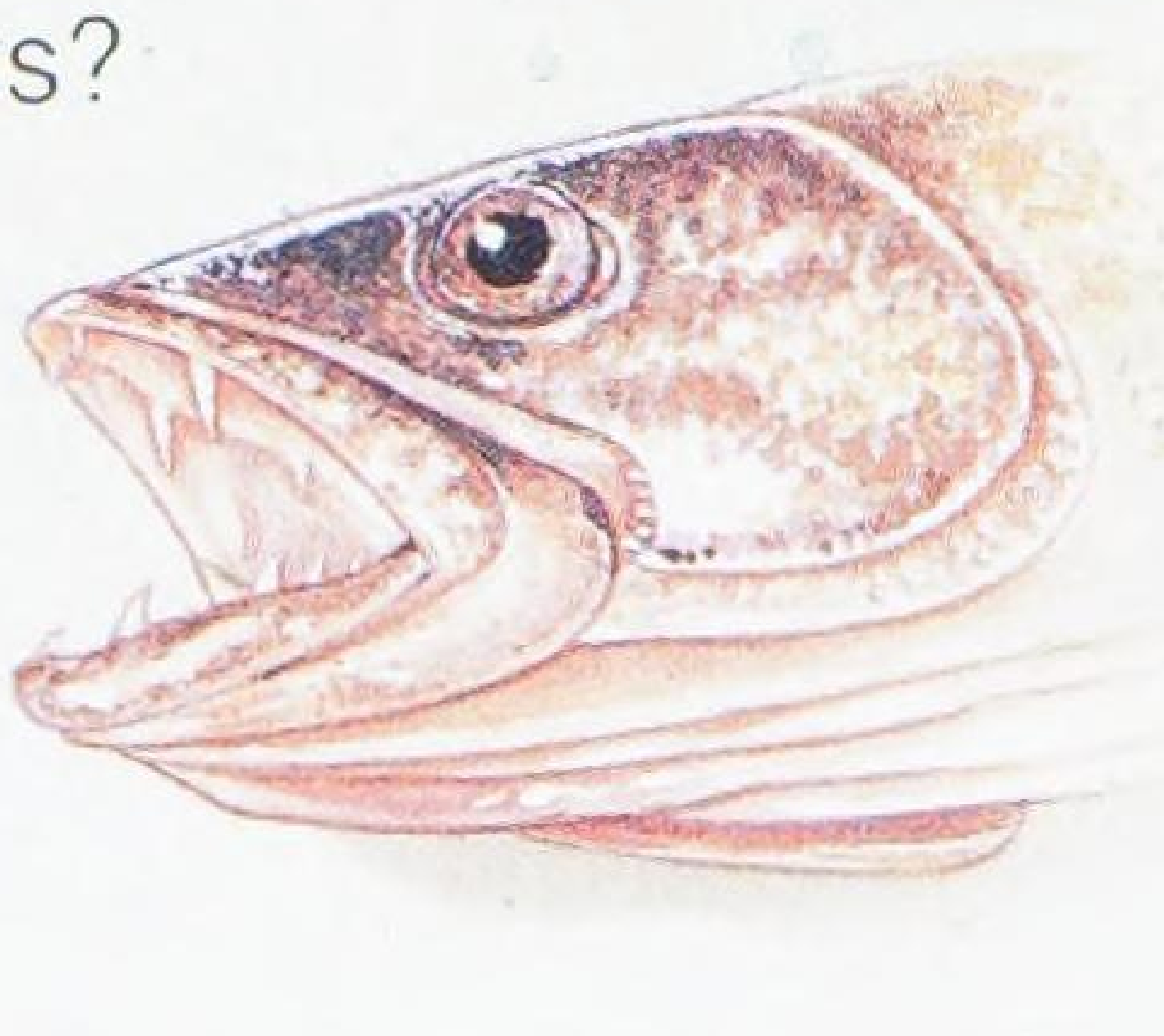
1. Does the animal have a backbone?
YES Go to 2.
NO Invertebrate



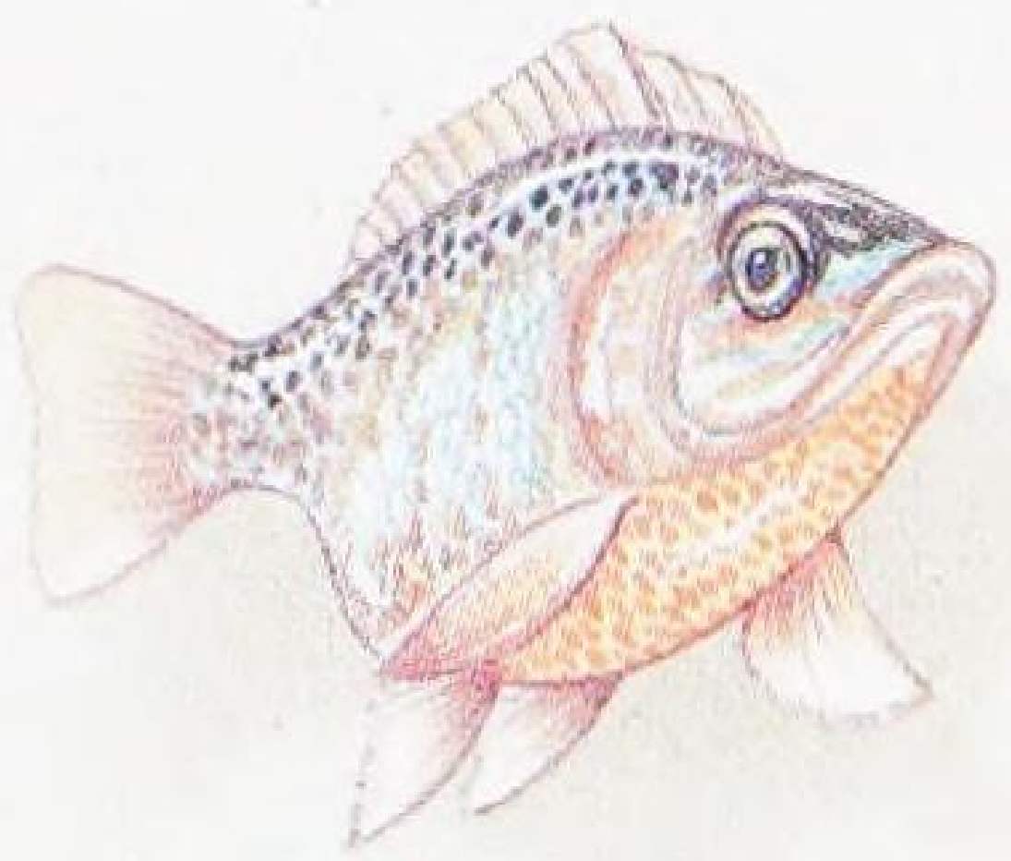
2. Does the animal have feathers?
YES Class Aves
NO Go to 3.



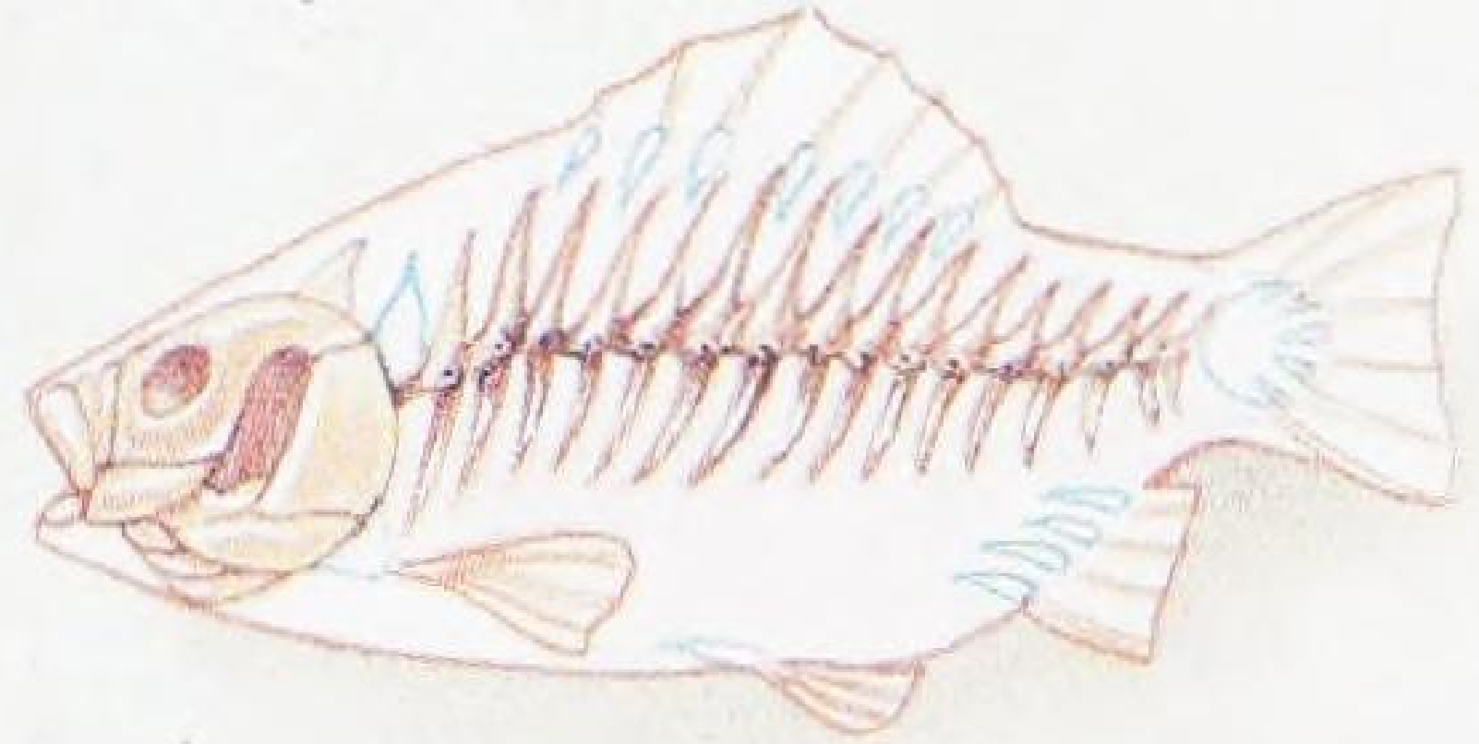
3. Does the animal have jaws?
YES Go to 4.
NO Class Agnatha



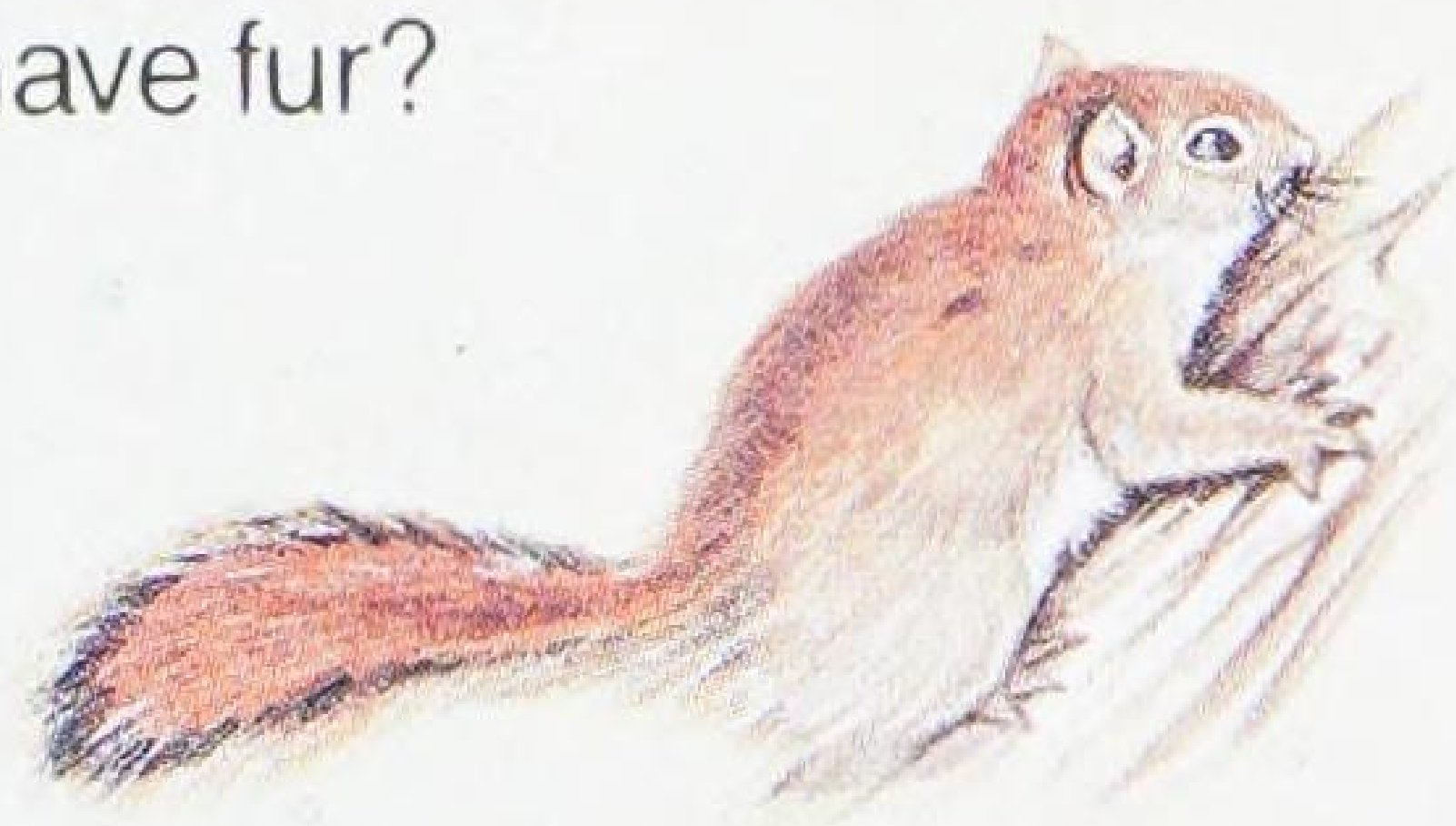
4. Does the animal have paired fins?
YES Go to 5.
NO Go to 6.



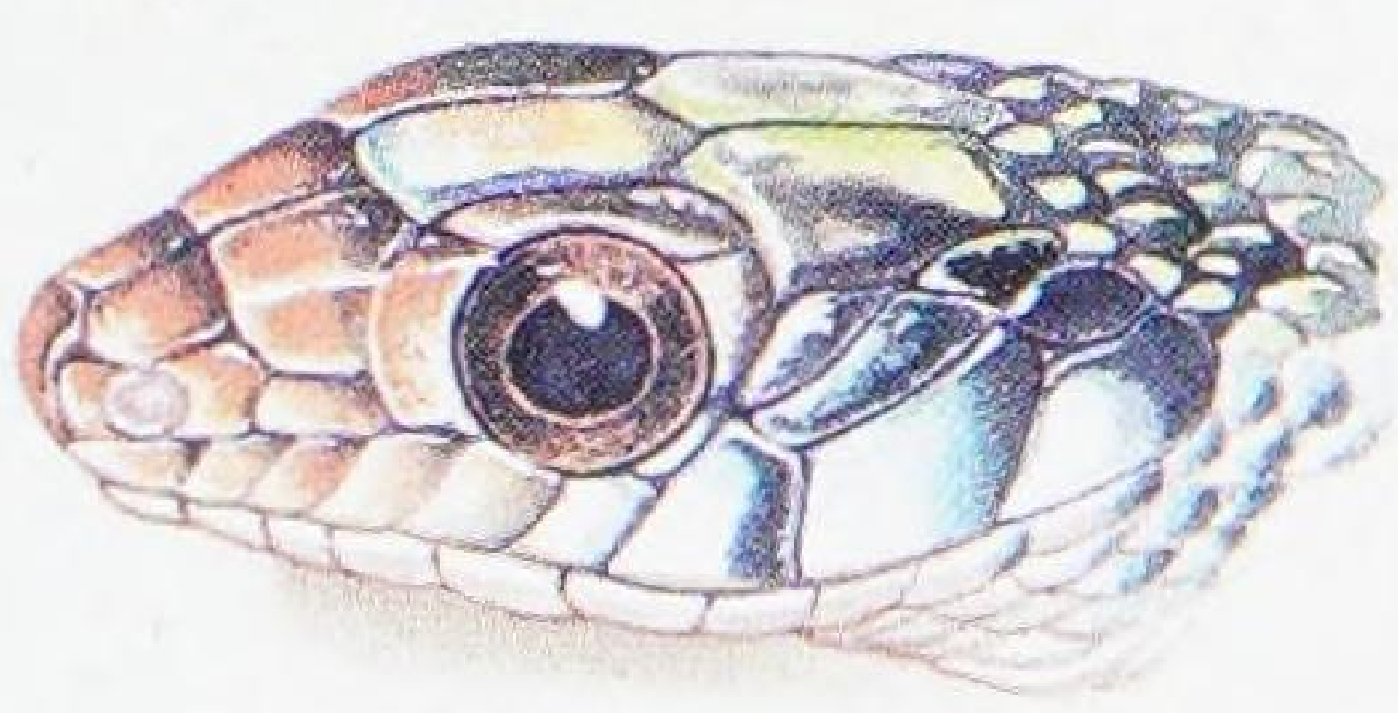
5. Does the animal have a bony skeleton?
YES Osteichthyes
NO Chondrichthyes



6. Does the animal have fur?
YES Mammal
NO Go to 7.



7. Does the animal have skin scales?
YES Reptilia
NO Amphibia



CHAPTER REVIEW

SUMMARY

16-1: Birds

1. Birds are warm-blooded organisms that are covered with feathers and lay eggs. Their front legs are modified into wings.

2. The adaptations birds have for flight are: wings; feathers; a light, strong skeleton; and efficient body systems.

3. Birds lay eggs enclosed in hard shells. Most birds incubate their eggs until hatching.

16-2: Mammals

1. Mammals are warm-blooded vertebrates with hair that have mammary glands that produce milk.

2. There are three groups of mammals: Mammals that lay eggs are monotremes. Mammals that have pouches for the development of their embryos are marsupials. Mammals whose offspring develop within the uterus with a placenta are placental mammals.

16-3: Science and Society: Saving the Manatee

1. Manatees are large aquatic mammals that belong to the order Sirenia. Adults weigh about half a ton. They live along the coasts in tropical and subtropical regions.

2. The major threats to manatees today are poachers, injury from boats, and habitat destruction.

KEY SCIENCE WORDS

a. **carnivores**
b. **contour feathers**
c. **down feathers**
d. **gestation period**
e. **herbivores**
f. **incubate**
g. **mammals**
h. **mammary glands**
i. **manatees**
j. **marsupials**
k. **monotremes**
l. **omnivores**
m. **placenta**
n. **placental mammals**
o. **poaching**
p. **preening**
q. **umbilical cord**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. plant-eaters
2. keep eggs warm
3. mammals whose embryos develop inside a uterus
4. feathers birds use for flying
5. animals that eat both plants and animals
6. glands that produce milk
7. feathers that help to insulate
8. activity of rubbing oil onto feathers
9. structure containing blood vessels that attaches embryo to the placenta
10. pouched mammals

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. A(n) _______ is a flightless bird.
   a. duck **c.** owl
   b. oriole **d.** ostrich
2. Wings of birds are not used for _______ .
   a. flying **c.** balancing
   b. swimming **d.** eating
3. Birds crush and grind food in the _______.
   a. crop **c.** gizzard
   b. stomach **d.** small intestine
4. Omnivores are mammals that eat _______.
   a. plants
   b. animals
   c. plants and anmals
5. A _______ is an example of a marsupial.
   a. cat **c.** kangaroo
   b. human **d.** camel
6. Egg-laying mammals are called _______.
   a. marsupials **c.** placental
   b. monotremes **d.** chiropterans
7. _______ have mammary glands with no nipples.
   a. Marsupials **c.** Placental mammals
   b. Monotremes **d.** Lagomorphs
8. Teeth specialized for tearing are _______.
   a. canine **c.** molars
   b. incisors **d.** premolars
9. _______ is hunting animals illegally.
   a. Placental **c.** Poaching
   b. Incubate **d.** Omnivore
10. Humans and monkeys are _______.
    a. Primates **c.** Edentates
    b. Carnivores **d.** Cetaceans

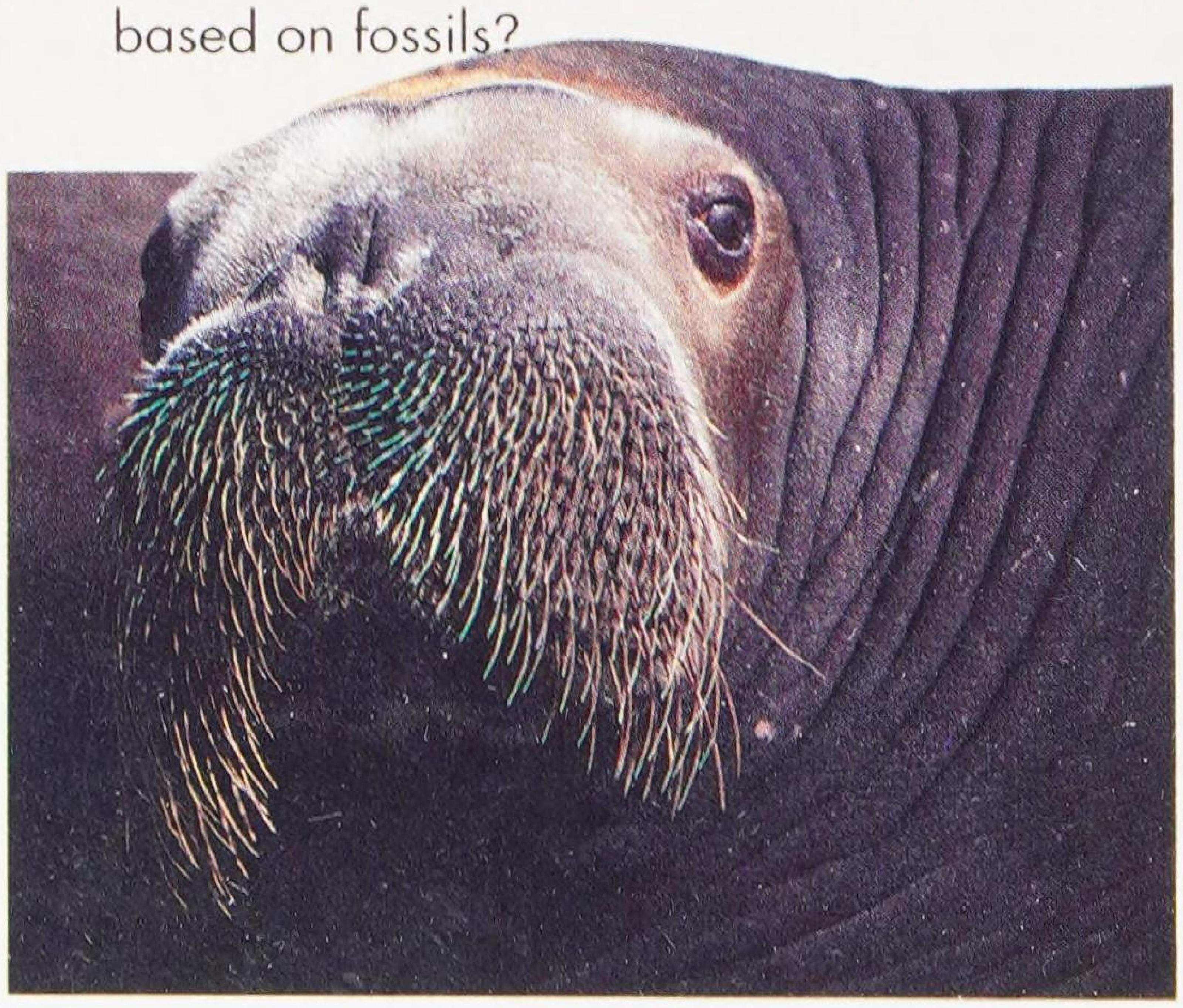
USING LAB SKILLS

11. In Activity 16–1 on page 378, you observed the structure of feathers. Based on your observations, explain why down feathers of birds are used to make warm coats for humans. Examine some synthetic materials used in making warm coats and compare them with down feathers. How are they alike? How are they different?
12. In the MINI-Lab on page 380, you looked at some of your own hairs. Examine cat, dog, or horse hair to compare them with human hair.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Why is it incorrect to tell someone who eats very little that he or she "eats like a bird"?
14. There are far more species of placental mammals than of marsupials or monotremes. Why do you think this is so?
15. Explain how the feet of birds are adapted to where they live.
16. Why is it difficult to study the origin of birds based on fossils?



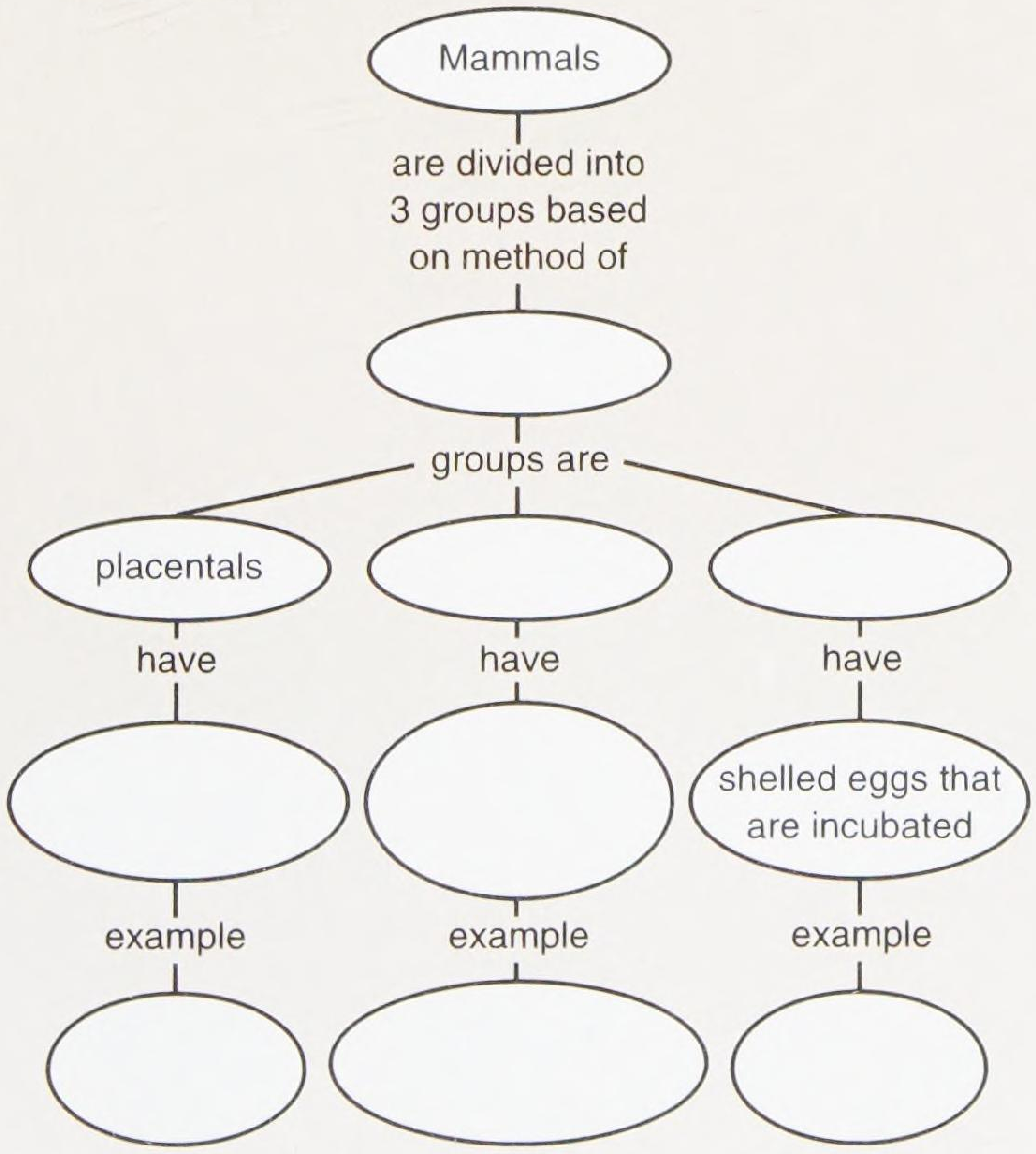
APPLY

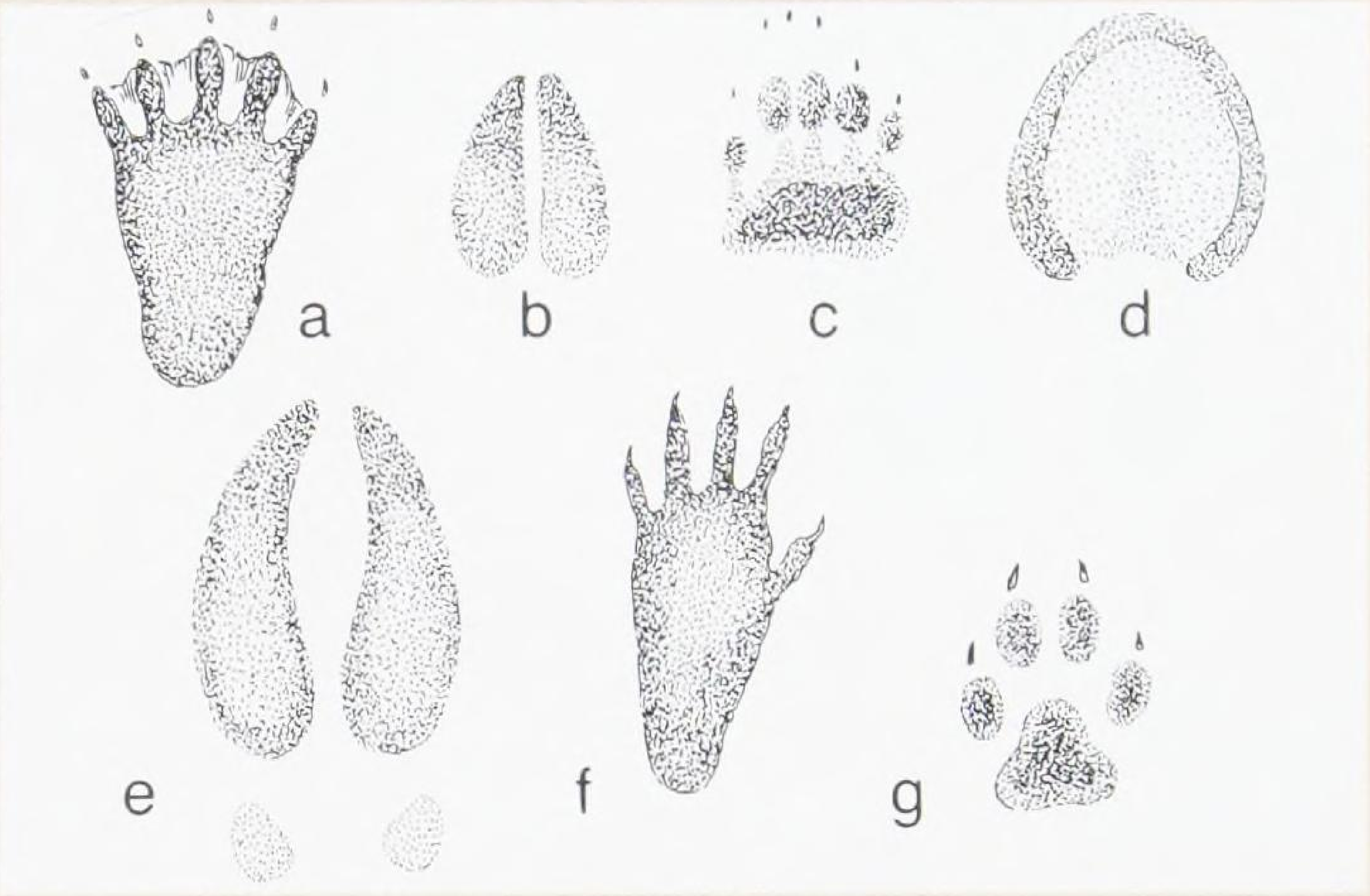
17. Discuss the differences in reproduction between birds and reptiles.
18. Name a mammal group that probably doesn't have sweat glands and explain why it doesn't.
19. Which type of bird would have lighter wing bones—ducks or turkeys? Explain.
20. What features of birds allow them to be fully adapted to life on land?
21. Which mammal group has the best adaptations for the survival of its embryo? Why?

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Sequencing:** Sequence the order in which food passes through a bird's digestive system.
2. **Concept Mapping:** Complete the concept map describing the groups of mammals.


Mammals
are divided into 3 groups based on method of
groups are
placentals
have
have
have
shelled eggs that are incubated
example
example
example



3. **Observing and Inferring:** Look at the diagrams of animal tracks. Decide which track belongs to which type of mammal by using Table 16-1. Fill in the chart. Describe how each animal's foot is adapted to its environment.

Animal	Track	Adaptation
Bear		
Beaver		
Cheetah		
Deer		
Horse		
Moose		
Raccoon		

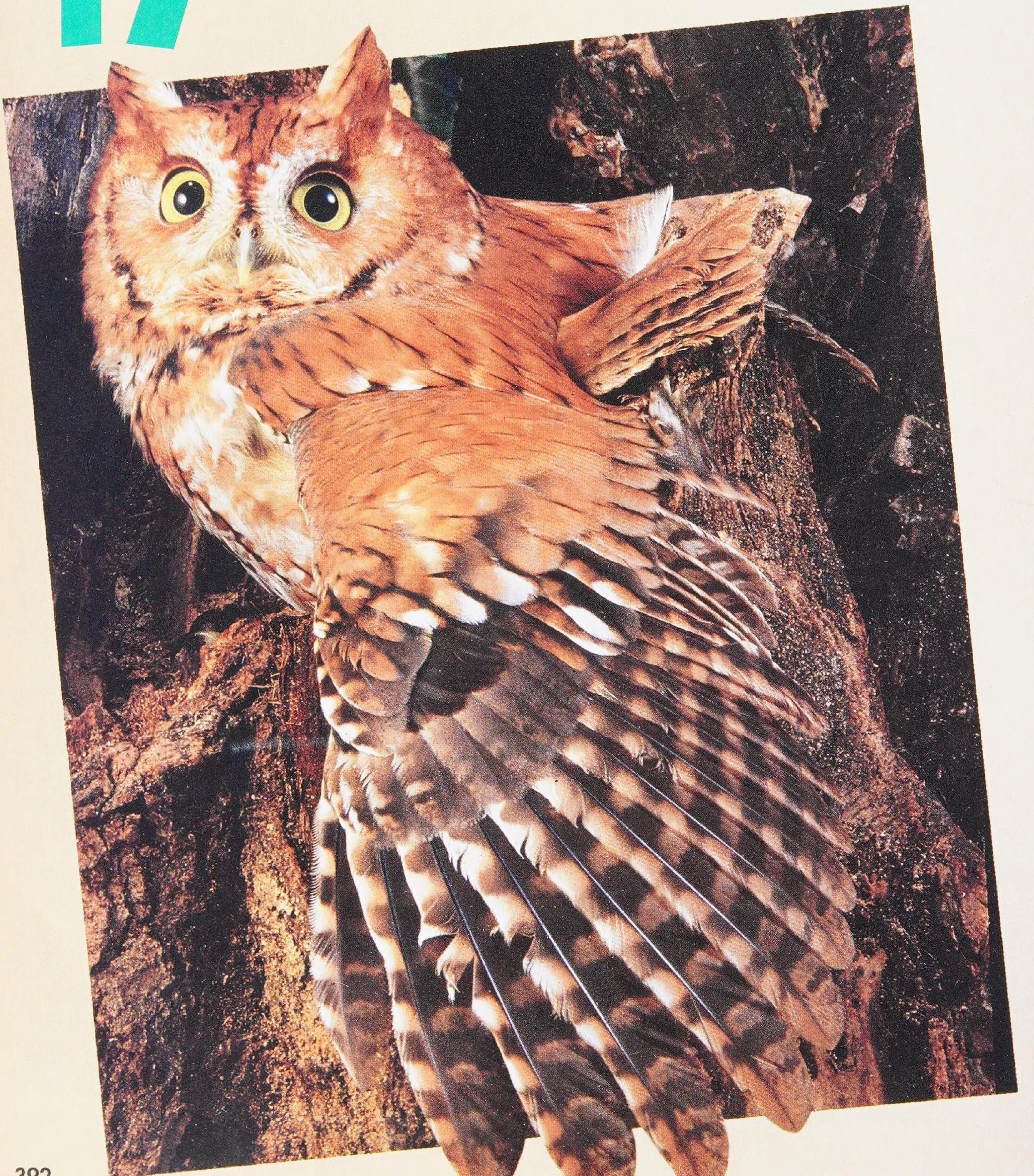
4. **Comparing and Contrasting:** Compare and contrast the teeth of herbivores, carnivores, and omnivores. How is each tooth type adapted to the animal's diet?
5. **Classifying:** You discover three new species of mammals. The traits of each species is as follows: Mammal 1—swims and eats plants; Mammal 2—flies and eats fruit; Mammal 3—runs and hunts. Classify each mammal into its correct group.

PROJECTS

1. Research the birds in your area. Find out what they eat and the types of nests they build.
2. Write to the National Wildlife Federation about endangered birds and mammals. What is being done to save these animals?

CHAPTER

17 Animal Behavior



Owls fluff up their feathers and spread their wings to appear larger when threatened. You quickly pull your hand away from a hot stove or iron, and blink your eyes when you see something rushing toward your face. Do organisms learn these actions, or do they occur naturally?

FIND OUT!

Do this simple activity to find out if some simple responses of organisms are learned or natural.

Obtain a piece of clear plexiglass and a wadded up sheet of paper from your teacher. Have a partner hold the plastic a few inches from his or her face. Stand three feet away and gently toss the wadded up paper toward your partner's face. *Observe* what happened to his or her eyes. Toss the paper ball again. This time tell your partner not to blink. Was he or she successful? Do you think this behavior is learned, or does it occur naturally? Do you think it is good for some behaviors to occur naturally?

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 17-1 Types of Behavior
- Innate Behavior
- Learned Behavior

Section 17-2 Behavioral Adaptations
- Territorial Behavior
- Courtship Behavior
- Social Behavior
- Cyclic Behavior

Section 17-3 Science and Society
Rehabilitation of Wild Animals
- Saving Injured Animals
- Return to the Wild

Previewing Science Skills

- In the **Skill Builders,** you will make and use tables and use variables, constants and controls.
- In the **Activities,** you will experiment, observe, and collect and record data.
- In the **MINI-Labs,** you will hypothesize, experiment, and graph data.

What's next?

The Find Out activity demonstrated some of the things you do naturally and are not learned. In this chapter you will learn more about these types of behaviors and about behaviors that are learned. You will also learn how animals behave to be able to survive in their environments.

17-1 Types of Behavior

New Science Words

behavior
innate behavior
reflex
instinct
learning
imprinting
trial and error
motivation
conditioning
insight

Objectives

- Distinguish between innate and learned behavior.
- Recognize reflex and instinctive actions and explain how they help organisms survive.
- Describe and give examples of imprinting, trial and error, conditioning, and insight.

Innate Behavior

When you come home from school, does your dog run to meet you, barking and wagging his tail? After you play with him a while, does he sit at your feet and watch every move you make? Why does he do these things? Dogs are pack animals that generally follow a leader. They have been living with people for about 50 000 years, so it's easy for a dog to adopt a human as his leader.

If you have a cat, she doesn't jump up and lick your face when you come home, does she? Cats are domestic animals too. Even though cats are happy living with people, they keep some traits of wild cats. Living with people doesn't change some of the behaviors of cats and dogs.

Behavior is the way an organism acts toward its environment. Anything in the environment to which an organism reacts is called a stimulus. You are the stimulus that causes your dog to bark and wag his tail. Your dog's reaction to you is a response.

Dogs and cats are quite different from one another in their behavior. They were born with certain behaviors, and they have learned others. A behavior that an organism is born with is an **innate behavior.** Such behaviors are inherited and they do not have to be learned.

Innate behavior patterns are usually correct the first time an animal responds to a stimulus. Kittiwakes are sea birds that nest on narrow ledges. The chicks stand still as soon as they hatch. The chicks of a related bird, the herring gull, which nests on the ground, move around as soon as they can stand. A kittiwake chick can't do this because one step could mean instant death. They don't have time to learn.

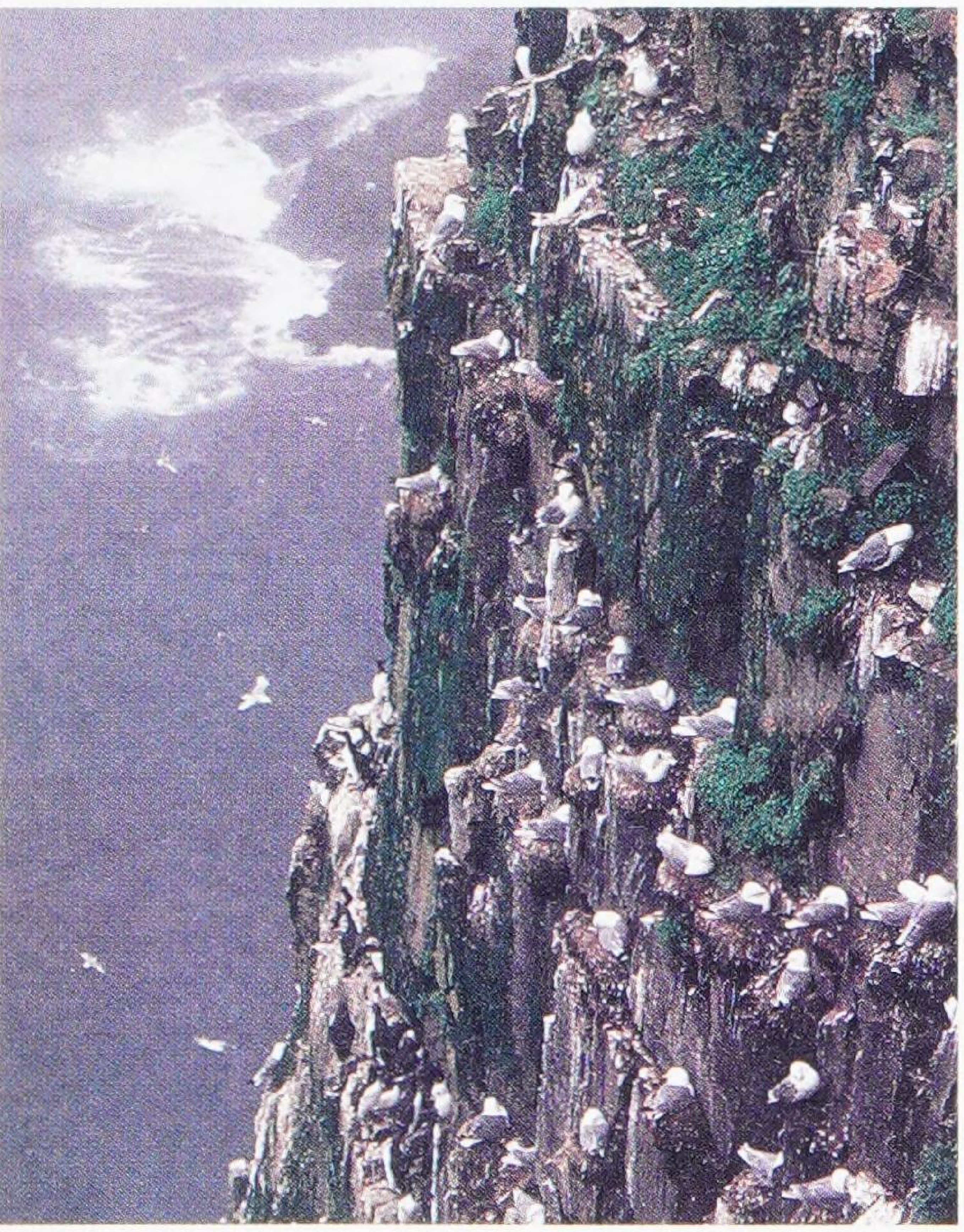


Figure 17-1. Some behaviors an animal is born with are necessary for survival.

The lives of most insects are too short for the young to learn from the parents. In many cases, the parents have died by the time the young hatch. And yet, every insect reacts automatically to its environment. A moth will fly toward a light, and a cockroach will run away from it. Fleas are attracted to warm-blooded animals by the heat their bodies give off, and fruit flies are attracted to the odor of overripe fruit. They do not have to spend time learning what to do.

The simplest innate behaviors are reflex actions. A **reflex** is an automatic response that does not involve the brain. Sneezing, shivering, yawning, jerking your hand away from a hot surface, and blinking your eyes when something is thrown toward you are all reflex actions. All animals have reflexes. The fur on your cat's back stands on end when she is frightened. An octopus changes colors when it senses danger.

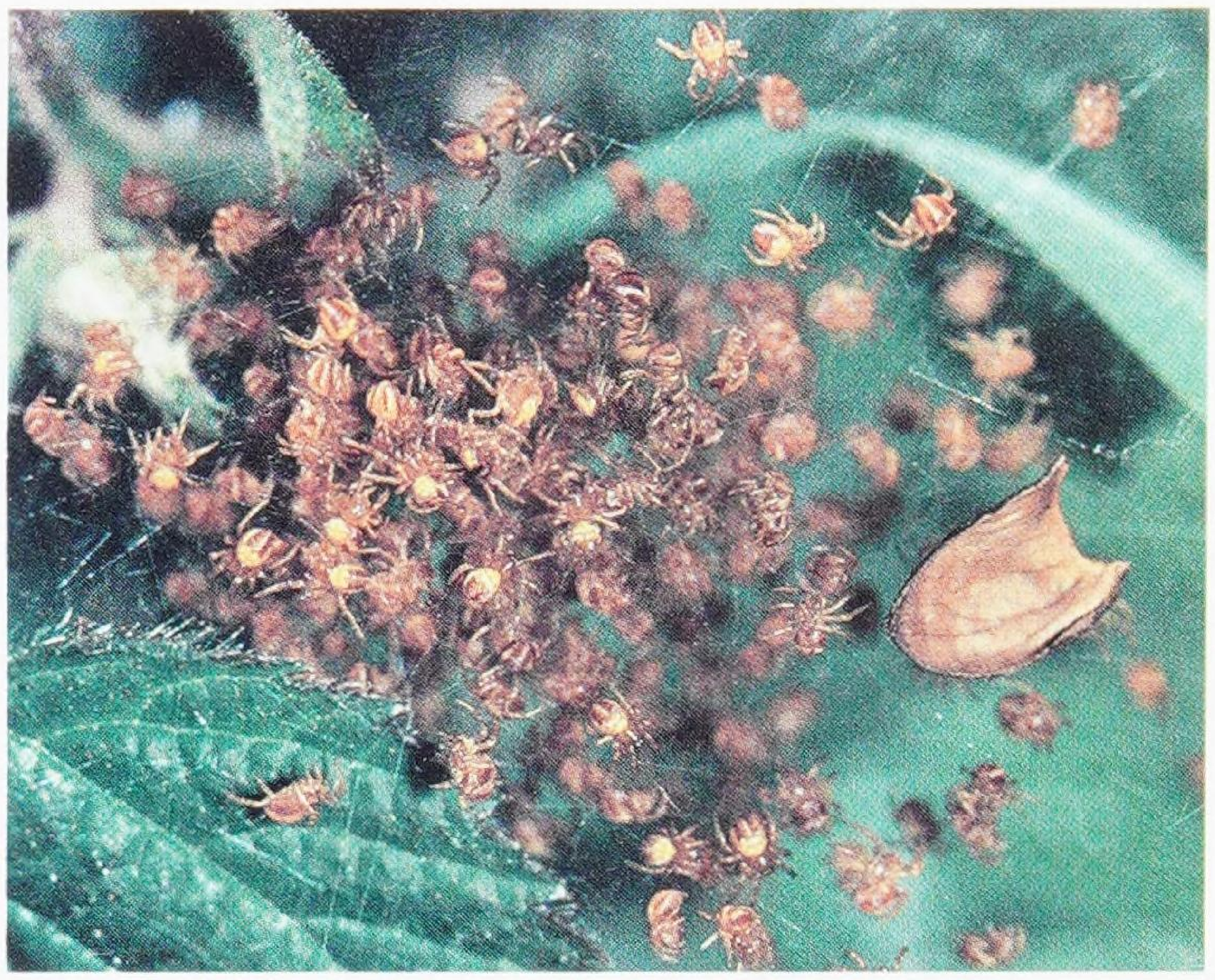


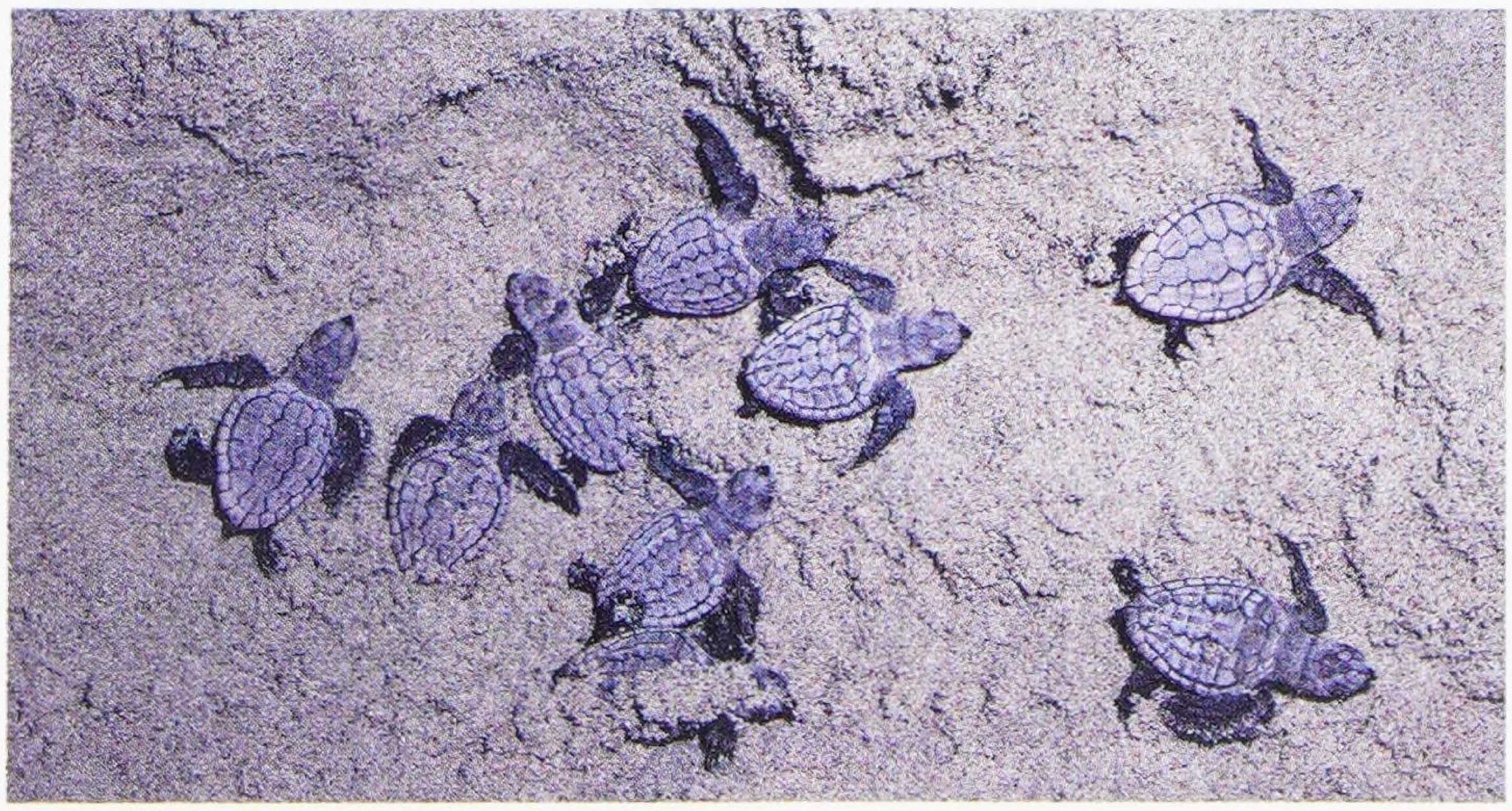
Figure 17-2. Spiders must automatically respond to their environment. There is no time for learning in their short life cycle.

During a reflex, a message passes from a sense organ along the nerve to the spinal cord and back to the muscles. The message does not go to the brain. You are aware of the reaction only after it has happened. A reflex is not the result of conscious thinking.

An **instinct** is a complex pattern of innate behavior. Have you ever watched a spider spin a web? Spinning a web is very complicated, and yet spiders spin webs correctly on the first try. Unlike reflexes, instinctive behaviors may have several parts and take weeks to complete. Instinctive behavior begins when the animal recognizes a stimulus and continues until all parts of the behavior have been performed.

In Your JOURNAL

In your Journal, make a list of some of the problems of using animals (or humans) in behavioral studies.



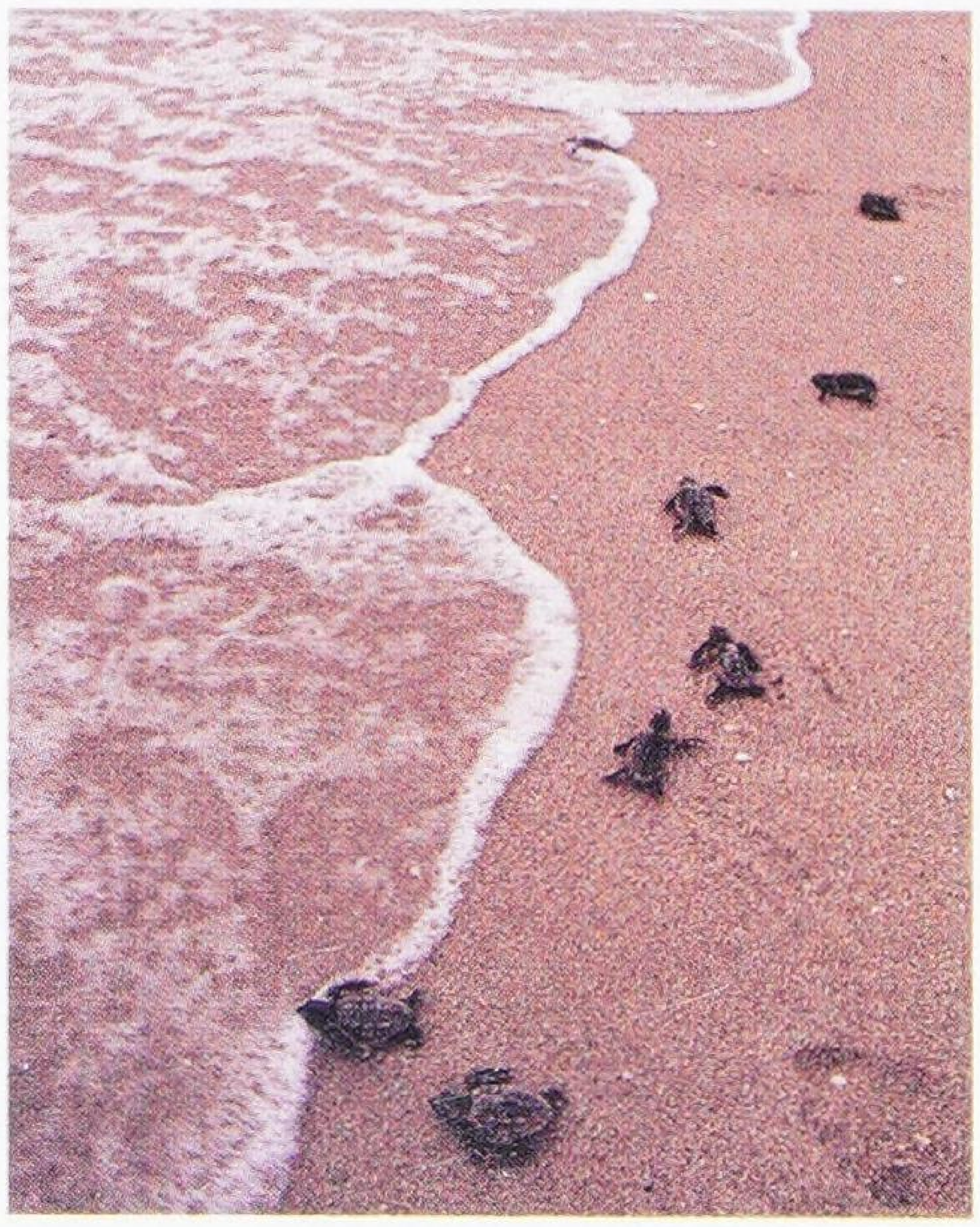


Figure 17-3. When sea turtles hatch, they instinctively run to the ocean.

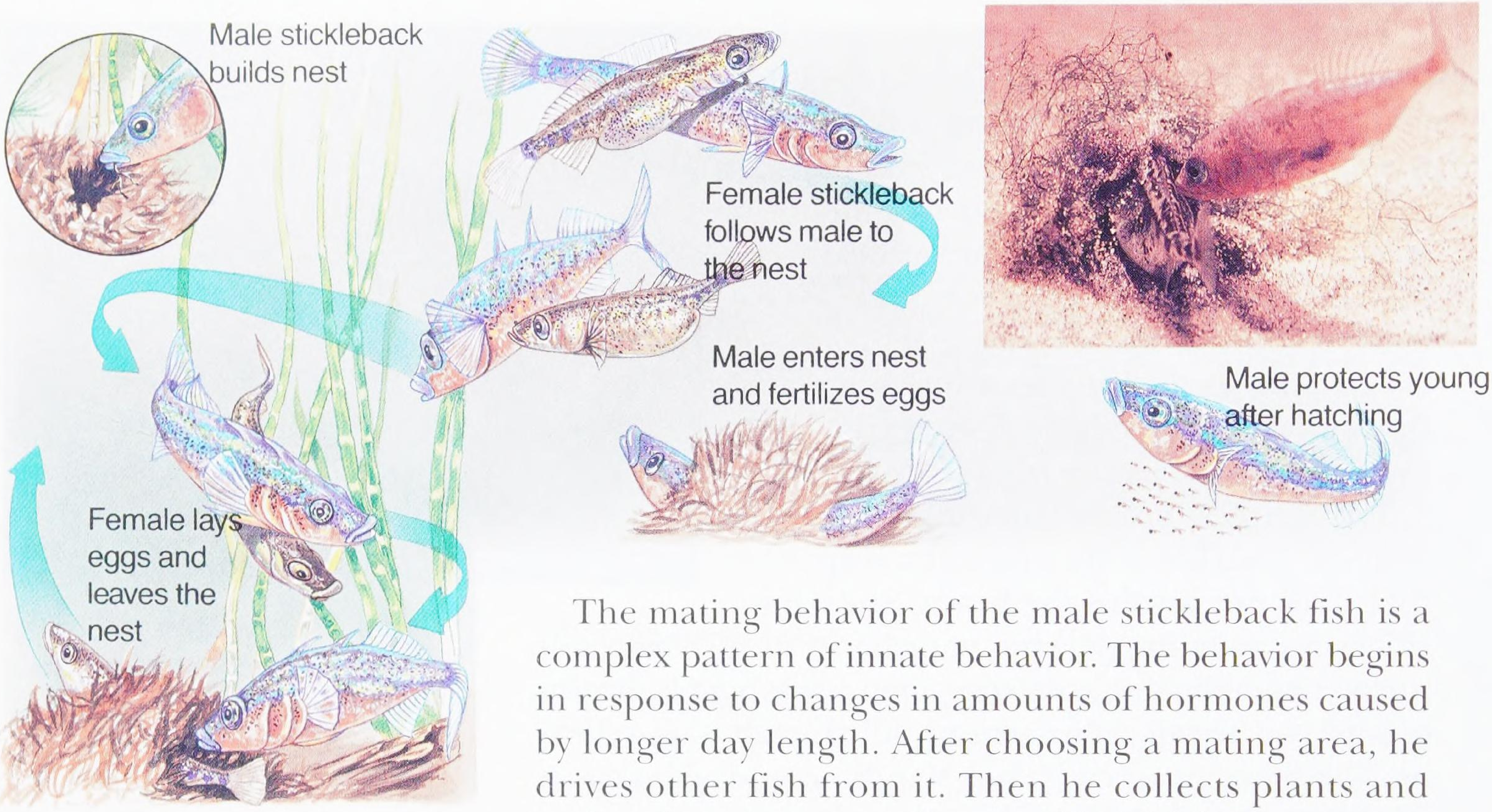

Male stickleback builds nest
Female stickleback follows male to the nest
Male enters nest and fertilizes eggs
Male protects young after hatching
Female lays eggs and leaves the nest

Figure 17-4. The male stickleback fish does not learn mating behavior. It is a complex innate behavior pattern.

The mating behavior of the male stickleback fish is a complex pattern of innate behavior. The behavior begins in response to changes in amounts of hormones caused by longer day length. After choosing a mating area, he drives other fish from it. Then he collects plants and makes them into a small mound in which he creates a tunnel. The tunnel becomes his nest. Meanwhile, his normally dull, brown-colored body changes to bright red on the underside and bluish-white on top. When a female enters the mating area, he does a zigzag dance to lead her into the nest. She lays her eggs in the nest and swims away. The male fertilizes the eggs and stays with them. When the young hatch, he protects them until they are well developed. All male sticklebacks are born with this pattern of behavior. Even if young sticklebacks are not raised with other sticklebacks, they follow the same behavior pattern.

Figure 17-5. Mammals have many more learned behaviors than other animals.

Learned Behavior

All animals have both innate and learned behaviors. **Learning** is a behavior that develops through experience. Instinct almost completely determines the behavior of insects, spiders, and other arthropods. These animals are able to learn very little, so their survival depends on innate behavior.

Fish, reptiles, amphibians, birds, and mammals can learn more than invertebrates. Fish behave more by instinct than birds. Birds show more instincts than mammals. In humans, babies suckle, smile, and grasp instinctively, but as they grow older, most of their behavior is learned.

Instincts can be modified by learning. Grouse and quail chicks leave their nest the day they hatch. They can run and find food, but they can't fly. When something moves above them, they crouch down and keep perfectly still until the danger is past. They will crouch without moving even if the falling object is only a leaf. Older birds have learned that leaves will not harm them, but they too freeze when a hawk moves overhead.

Imprinting

You have probably seen young ducks following their mother. This is an important behavior because the adult bird has had more experience in finding food, escaping predators, and getting along in the world. **Imprinting** is a type of learning in which an animal forms a social attachment to another organism within a specific time period after birth or hatching.

Konrad Lorenz, an Austrian naturalist, developed the concept of imprinting. Working with geese, he discovered that a gosling follows the first moving object it sees after hatching. It recognizes the moving object as its parent. It later recognizes similar objects as members of its own species. This behavior works well when the first moving object a young goose sees is an adult female goose. But, goslings hatched in an incubator may see a human first and may imprint on her. Animals that become imprinted toward animals of another species never learn to recognize members of their own species.

Trial and Error

Can you remember when you learned to ride a bicycle? You probably fell many times before you learned to balance on the bicycle. But after a while you could ride without having to think about it. You have many skills that you have learned through trial and error. Skating and riding a bicycle are just a few.

Behavior that is modified by experience is called **trial and error** learning. Both invertebrates and vertebrates learn by trial and error. When baby chicks first learn to

Connect to... Chemistry

When a salmon hatches, the chemical makeup of the water around it is imprinted in its memory. As an adult, the salmon follows streams with a chemical makeup that most closely corresponds to this memory. Why is this imprinting important for salmon survival?

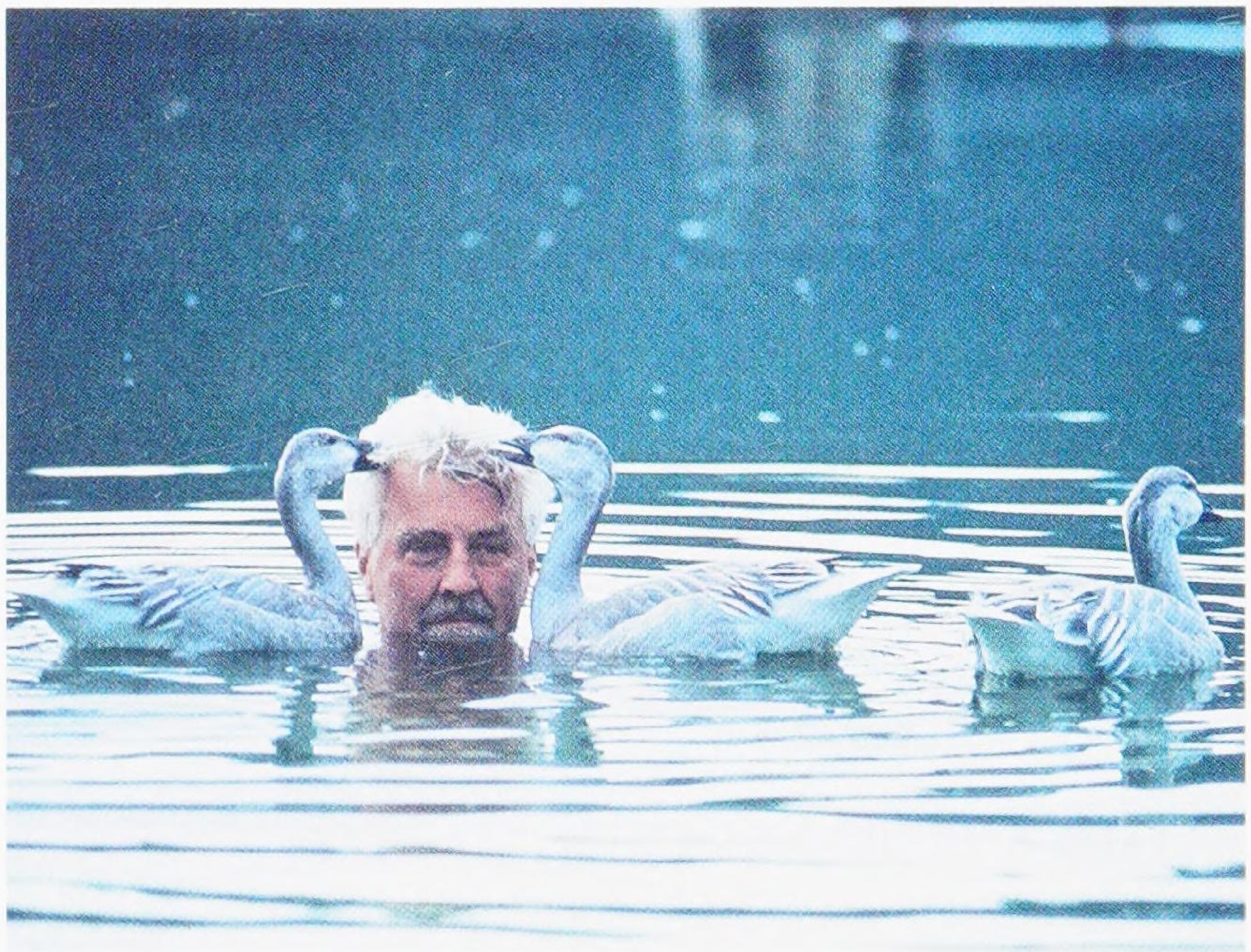


Figure 17-6. Young goslings may imprint on any object or organism present during hatching. Konrad Lorenz is shown here swimming with imprinted goslings.

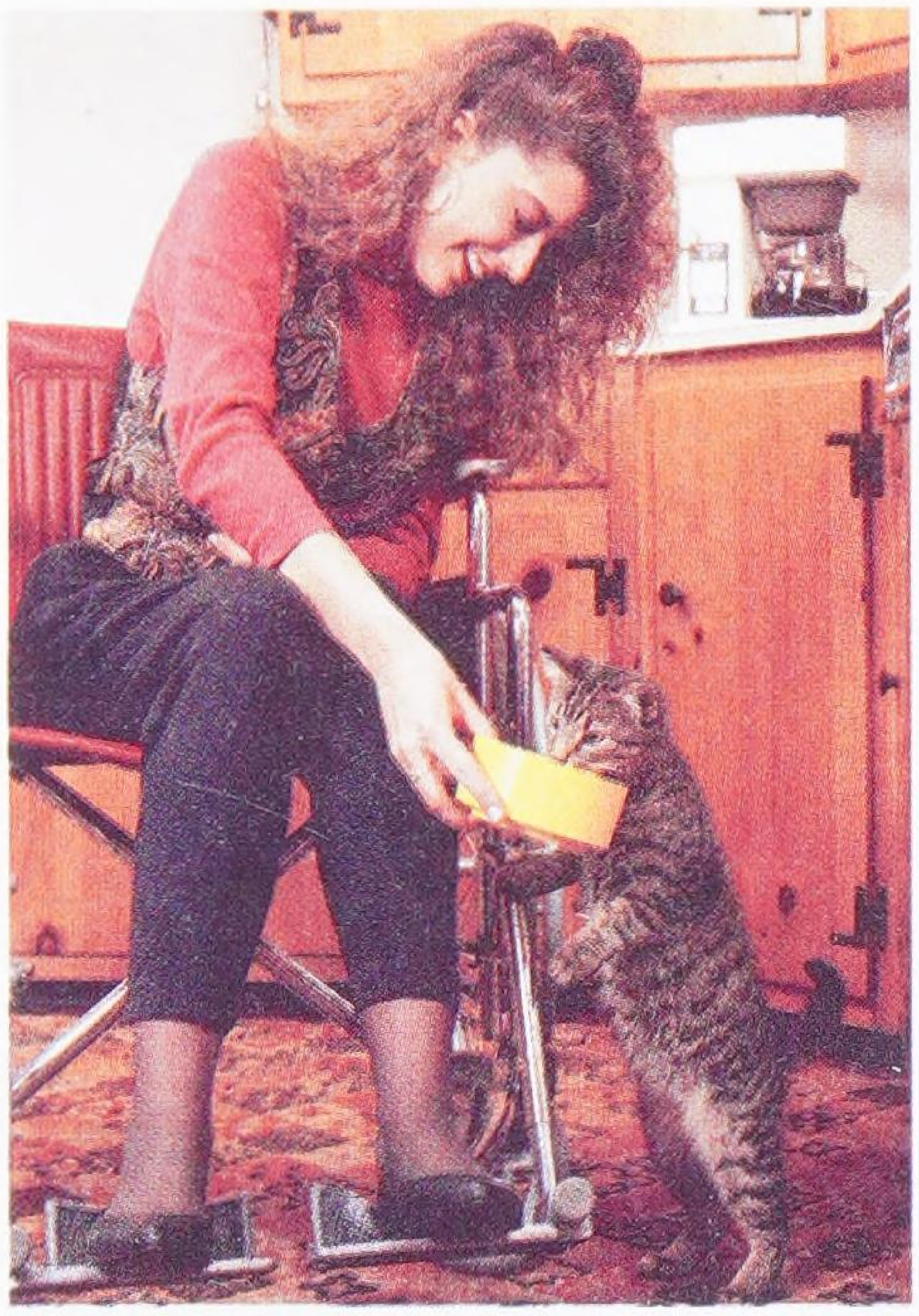


Figure 17-7. Many pets become conditioned to be fed at certain times of the day.

feed themselves, they peck at many spots before they get any food. As a result of trial and error, they soon learn to peck only at grain.

A particular stimulus may cause a different response in the same animal at different times. When your cat sees food, she will eat it if she's hungry, but if she has just eaten, she will ignore the food. For a hungry rat, the motive to learn a maze may be the food at the end of the maze. **Motivation** is something inside an animal that causes the animal to act. It is necessary for learning to take place.

Conditioning

Animals often learn new behaviors by conditioning. In **conditioning,** behavior is modified so that a response previously associated with one stimulus becomes associated with another. Russian scientist Ivan P. Pavlov was the first person to study conditioning. He knew that the sight and smell of food made hungry dogs secrete saliva. Pavlov

PROBLEM SOLVING

The Disappearing Lizards

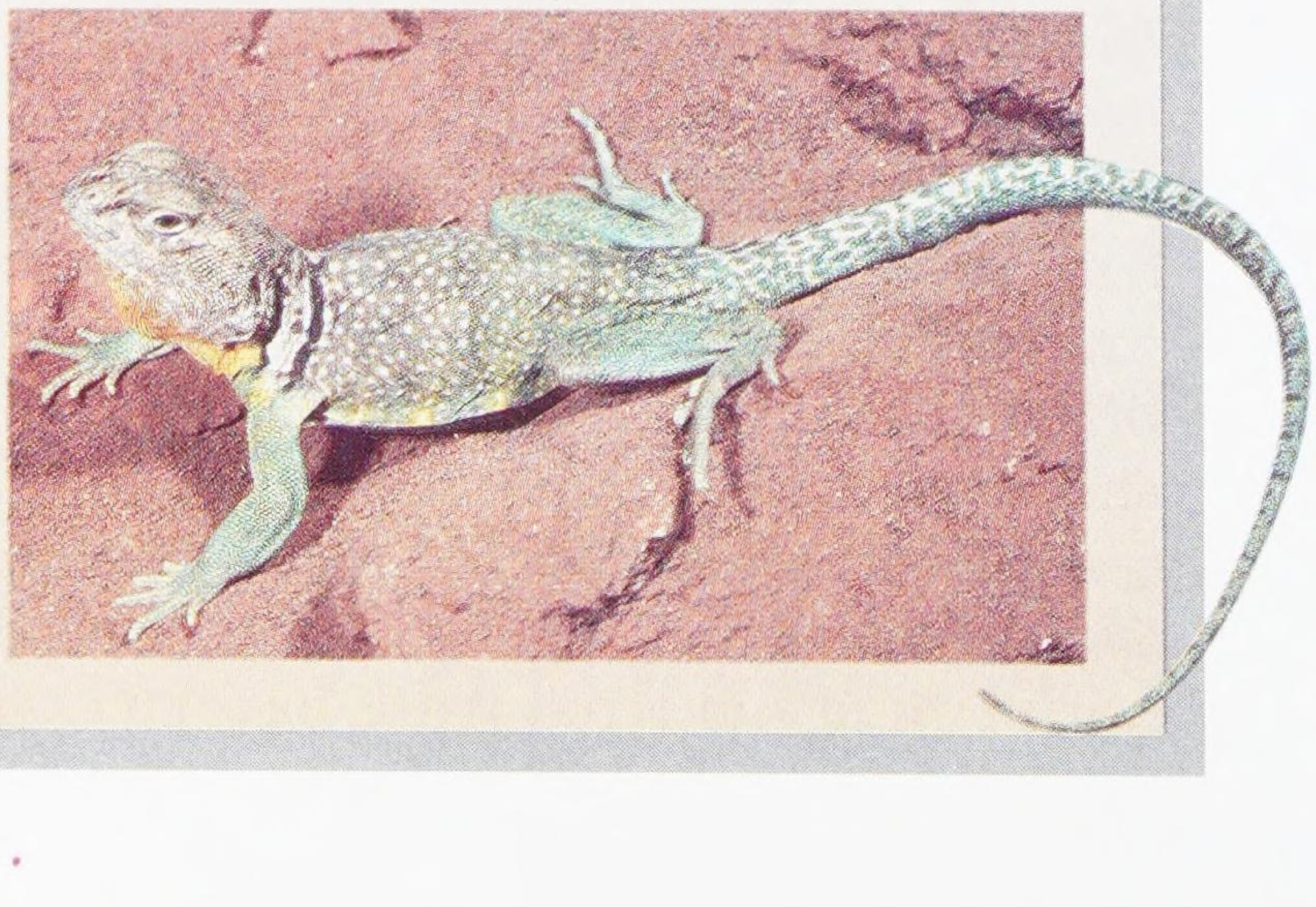
Julio's science class is studying vertebrate animals. His teacher asked each member of the class to choose a vertebrate animal, observe it for several days, and prepare a report.

Shortly after sunup, Julio went to a hot desert area near his home to observe lizards. Julio saw three lizards lying motionless on some rocks. He watched for a while, then went home for a cool drink. When he returned, the lizards seemed to have disappeared. The same thing happened on the next day.

One morning Julio stayed a little longer. One lizard left its rock and burrowed into the sandy soil. Soon, the other two lizards did the same thing. Then, on Saturday, Julio made more frequent visits to the rock. The lizards stayed underground until sunset when they dug out and began hunting for food.

Was the lizards' behavior innate or learned?

Think Critically: Use what you learned about cold-blooded animals to explain the behavior of the lizards.



added another stimulus. He rang a bell when he gave the dogs food. The dogs began to connect the sound of the bell with food. Then Pavlov rang the bell without giving the dogs food. The dogs secreted saliva when the bell was rung even though he did not show them food. The dogs were conditioned to respond to the bell.

The American psychologist John B. Watson demonstrated that responses of humans can also be conditioned. In one experiment, he struck a metal object each time an infant touched a furry animal. The loud noise frightened the child. In time, the child became frightened by the furry animal when no sound was made.

Insight

When you solve a math problem, do you use what you have previously learned in math to solve the problem? **Insight** is a form of reasoning that enables animals to use past experiences to solve new problems. In Wolfgang Kohler's experiments with chimpanzees, a bunch of bananas was placed too high for the chimpanzees to reach. Chimpanzees piled up boxes found in the room, climbed up on them, and reached the bananas. Much of adult human learning is based on insight. Younger children learn by trial and error.

MINI-Lab

How does insight help you solve problems?

Obtain a chain of 15 safety pins. Count the safety pins on the chain to be sure there are 15. Make a **hypothesis** as to the *fewest* number of times you can open and close pins to break the chain into the following:

5 pins attached
4 pins attached
3 pins attached
2 pins attached, and
1 alone

Each open-and-close counts as **one.** Test your hypothesis and compare with those of your classmates. (All pins must be closed at the end!)

SECTION REVIEW

1. Compare innate behavior with learned behavior.
2. Compare a reflex with an instinct.
3. Describe the four types of learned behavior.
4. How are trial and error and insight behaviors important to humans?
5. **Apply:** A family moves into a new home near an airport. They are awakened by the planes during the first few nights. Explain why after a week or two, they stop waking up even though the planes continue to fly.
6. **Connect to Chemistry:** Write a paragraph about how some drugs are used in a beneficial way to modify behavior.

Making and Using Tables

Skill Builder

Make a table that shows the kinds of innate and learned behaviors in this section. Include examples of each. If you need help, refer to Making and Using Tables in the **Skill Handbook** on page 690.

DESIGNING AN EXPERIMENT

ACTIVITY 17–1

Investigating Conditioning

Have you ever smelled cookies baking and had your mouth water? From this chapter, you know that the smell of baking cookies is a stimulus that causes the response of mouth watering. In conditioning, behavior is modified so that a response previously associated with one stimulus becomes associated with another. In this activity, you will be the scientist and find out if conditioning in goldfish can be demonstrated.

Getting Started

In preparation for designing your experiment, answer the following questions:

1. What question are you investigating?
2. How do fish move, breathe, and get food?
3. What variables are important in this experiment?

Safety Notes

Use extreme care when working with live animals.

Hypothesis

What is your **hypothesis?** What is the reasoning behind your hypothesis? Share this information with your group. Choose the best idea that can be investigated in the classroom and decide on one hypothesis.

Brainstorm

In a group, make a list of possible ways to test your hypothesis.

Experimental Plan

- Design your experiment to test one variable. Make sure you plan to collect quantitative data.
- In a numbered list, similar to a recipe, make a set of directions that anyone can follow to do the experiment.
- Make a list of the materials and the quantities needed to do the experiment.

Answer the Following Questions

1. Have you included a control?
2. What will you measure?
3. How many fish will you test?
4. How many times will you feed the fish and provide the stimulus at the same time?
5. Develop a table for collecting quantitative data.

Make sure your teacher has approved your experimental plan before you go further.

Data and Observations

1. Carry out your experiment.
2. *Record data* in your table as you perform the experiment.

Data Analysis and Interpretation

1. What stimulus did you use to condition the fish?
2. How long did it take for the fish to become conditioned?
3. Was your **hypothesis** supported by your data? Explain.
4. How does this experiment *relate* to what you are studying in class?
5. Write a brief conclusion based on your data.

Going Further

Based on your data and observations, design another experiment that would help to expand your conclusions or answer questions that came up in your mind as you conducted your experiment.

Behavioral Adaptations 17-2

Objectives

- Recognize the importance of behavioral adaptations.
- Explain how courtship behavior increases the chances of reproductive success.
- Evaluate the importance of social behavior and cyclic behavior.

New Science Words

territory
aggression
courtship behavior
social behavior
society
communication
cyclic behaviors
circadian rhythm
migration

Territorial Behavior

Many animals set up territories for feeding, mating, and raising young. A **territory** is an area that an animal defends from other members of the same species. Ownership of a territory is set up in different ways. Songbirds sing to set up territories. Sea lions bellow and squirrels chatter. Other animals leave scent marks. Some patrol the area to warn intruders.

Pet dogs and cats have territories. A dog often barks and nips at other dogs around its home. Cats and dogs mark their territories with urine. A cat out hunting will sniff for scent marks of other cats. If the scent marks are fresh, the cat will take another path.

The size of a territory varies with the species. Song sparrows have territories that are as large as 3000 square meters where they feed, mate, and nest. Gulls, penguins, and other water birds nest in large groups, but each male and his mate have their own territory. Male sea lions defend small territories that are used only for mating. Squirrels have large territories for feeding. Female lizards defend feeding territories, and male lizards defend mating areas.

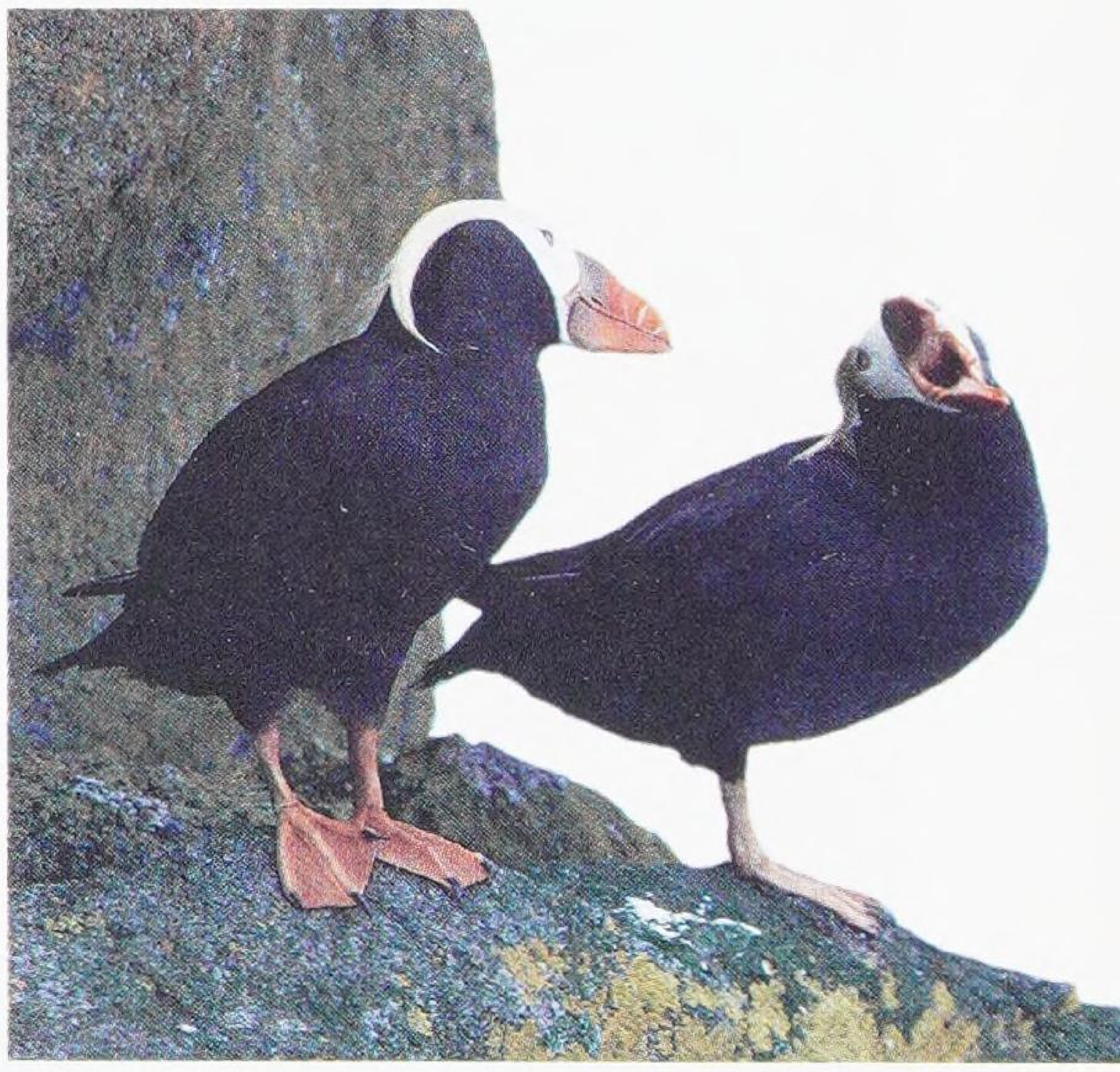


Figure 17-8. These puffins are defending their nesting territory.

Have you ever watched a dog approach another dog eating a bone? What happens to the appearance of the dog with the bone? The hair stands up on its back, the lips curl, and the dog makes growling noises. This behavior is aggression. **Aggression** is a forceful act used to dominate or control another animal. Fighting and threatening are aggressive behaviors animals use to defend their territories, protect their young, or to get food.

Aggressive behaviors seen in birds include letting the wings droop below the tail feathers, taking another's perch, and thrusting the head forward in a pecking motion. These behaviors are intended to avoid physical contact. Fighting wastes valuable energy. And a missing feather or two can greatly reduce a bird's ability to fly.

Animals seldom fight to the death. They rarely use their teeth, beaks, claws, or horns to fight members of their own species. These structures are used for killing prey or for defense against members of another species. To avoid being killed, a defeated animal shows submission by lowering its posture or retreating.

Courtship Behavior

Connect to... Chemistry

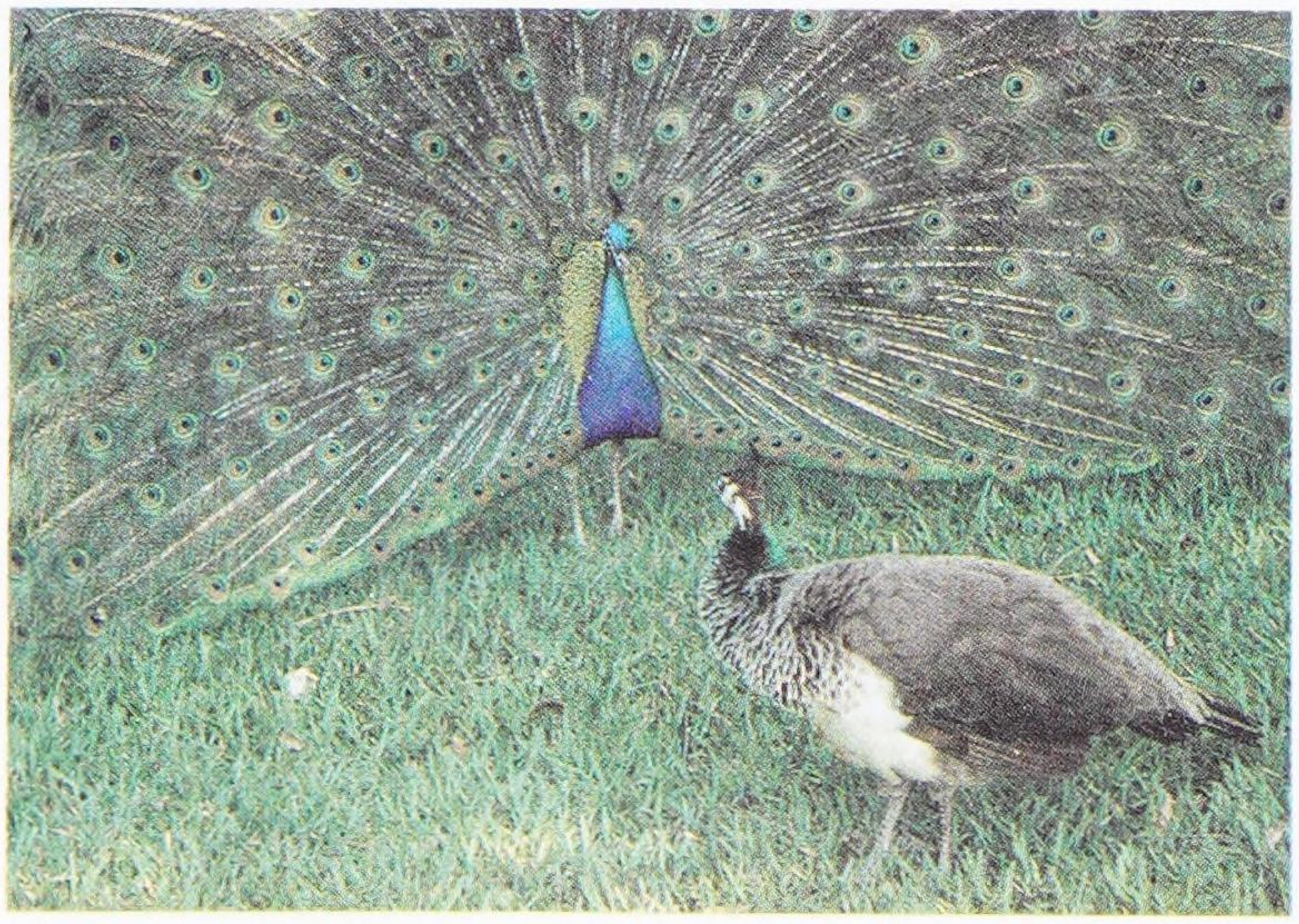
There are many kinds of courtship behaviors in nature. Find out what causes the flashes of light produced by male fireflies. How does this behavior help in firefly survival?

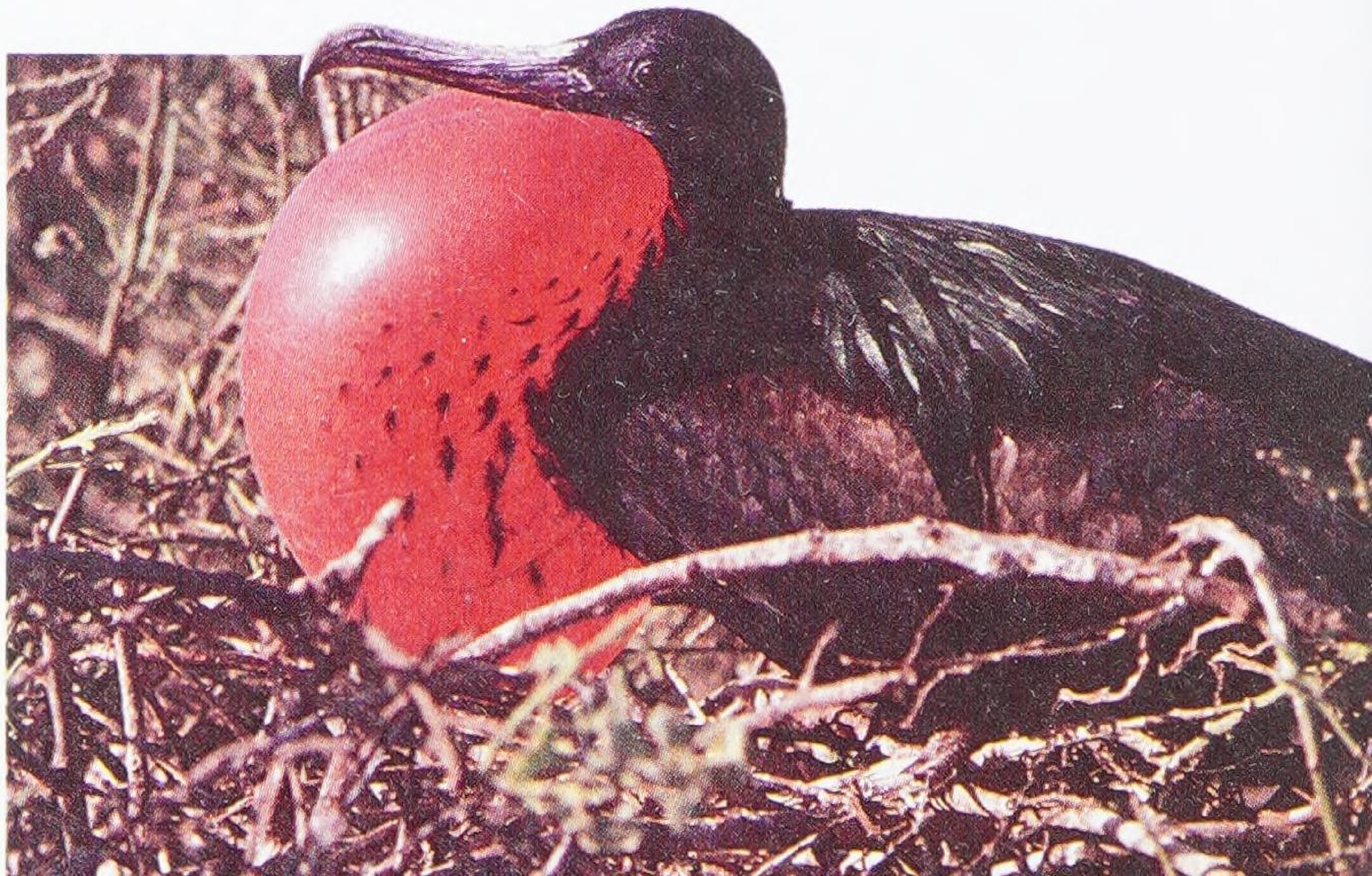
You have probably seen a male peacock spread the beautiful feathers on his lower back. The male frigate bird in Figure 17-9 has a bright red pouch on his throat that takes about 25 minutes to blow up. A male sage grouse fans his tail, fluffs his feathers, and blows up his two air sacs. These are examples of a behavior that both males and females of a species perform before mating. This type of behavior is called **courtship behavior.** Courtship behaviors allow male and female members of a species to recognize each other. They also allow males and females to be ready to mate at the same time. This helps provide reproductive success.

In most species, the males perform courtship displays to attract a mate. Songbirds sing. Other birds depend on bright colors and attention-getting movements or postures. Many species of birds move the head, wings, or other body parts. The response of the female may closely resemble the male's display, and so the two look as if they are dancing.

Some courtship behaviors allow males and females to find each other across distances. Male fireflies produce different

Figure 17-9. The male peacock (left) and the male frigate bird (right) are both trying to attract females with their displays.





patterns in their flashes of light. A female of the same species recognizes the pattern and flashes back. Female gypsy moths release chemical messengers called pheromones that attract males. Very small amounts of pheromone can attract male moths several kilometers away. Sound is another way males and females find each other. Insects such as crickets, grasshoppers, and locusts call to each other by sounds made by rubbing their legs or wings together. Frogs make sounds that can be heard hundreds of meters away.

In Your JOURNAL

Imagine you are a scientist who studies behavior. **In your Journal,** write a proposal to study the behavior of an animal that interests you. Be sure to be specific about what behavior you want to study and why you think the study is important.

Social Behavior

Do you know why geese fly in flocks and some fish swim in schools? Animals live together in groups for several reasons. One reason is that there is safety in large numbers. A wolf pack is less likely to attack a herd of musk oxen than an individual musk oxen. In some groups, large numbers of animals help keep each other warm. Penguins in Antarctica huddle together against the cold winds. Migrating animals in large groups are less likely to get lost than if they traveled alone.

Interactions among organisms of the same species are examples of **social behavior.** Social behaviors include courtship and mating, caring for the young, claiming territories, protecting each other, and getting food. These behaviors provide advantages for survival of the species.

Insects such as ants, bees, and termites live together in societies. A **society** is a group of animals of the same species living and working together in an organized way. Each member has a certain job. Usually there is a female that lays eggs, a male that fertilizes the eggs, and workers that do all the other jobs in the society.

Some societies are organized by dominance. Wolves usually live together in packs. In a wolf pack, there is a dominant female. The top female controls the mating of the other females. If there is plenty of food, she mates and allows the others to do so. If food is scarce, she allows less mating, and usually she is the only one to mate.

In all social behavior, communication is important. **Communication** is an exchange of information. How do you communicate with the people around you? Animals in a group communicate with sounds and actions. Alarm calls, pheromones, speech, courtship behavior, and aggression are all forms of communication.

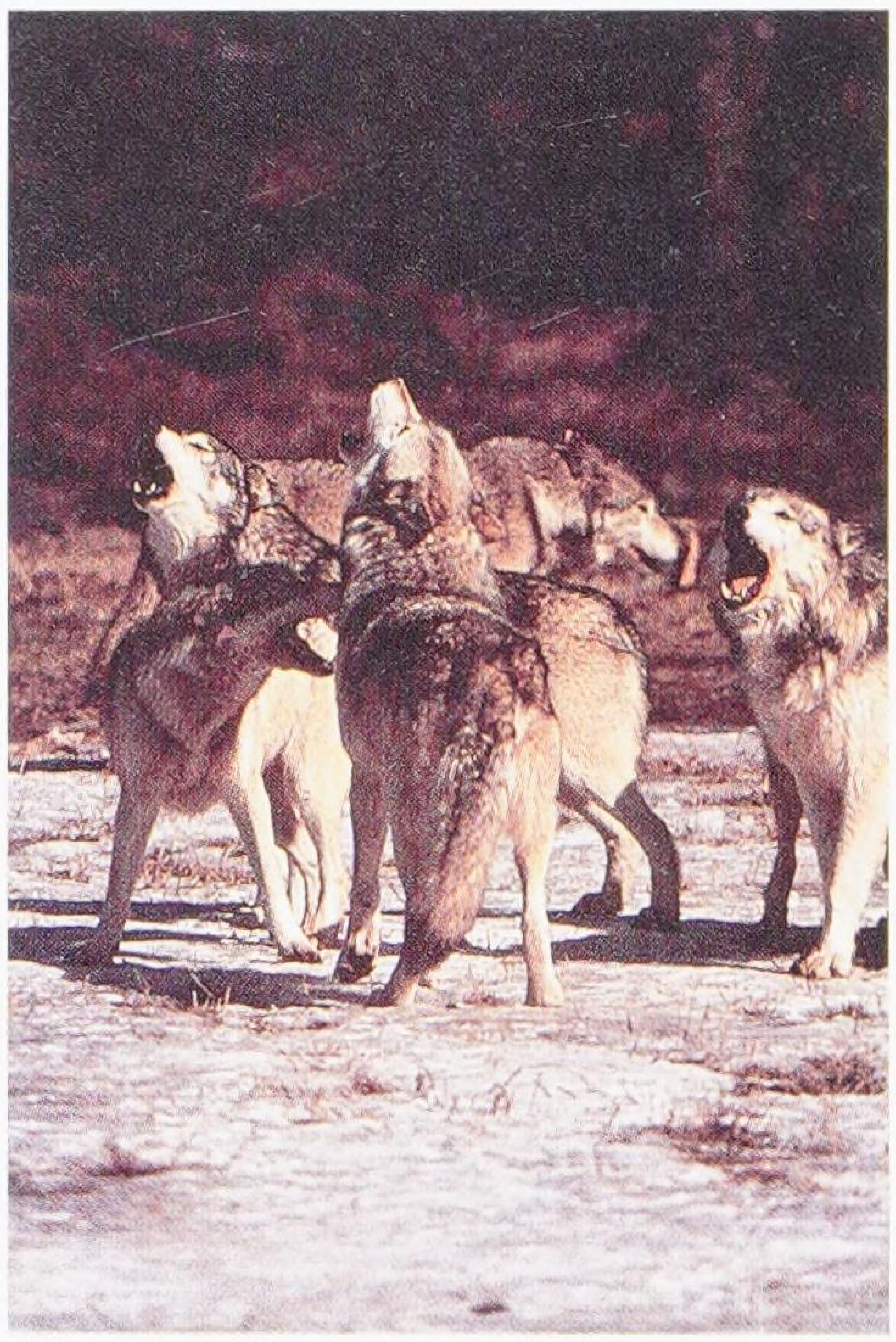


Figure 17-10. Wolves live together socially in packs. They hunt and raise their young together. Strong bonds are formed among members of the pack.

Cyclic Behavior

What determines when an owl sleeps and when it wakes up? Animals show regularly repeated behaviors such as feeding in the day and sleeping at night or the opposite. Many reproduce every spring and migrate every spring and fall.

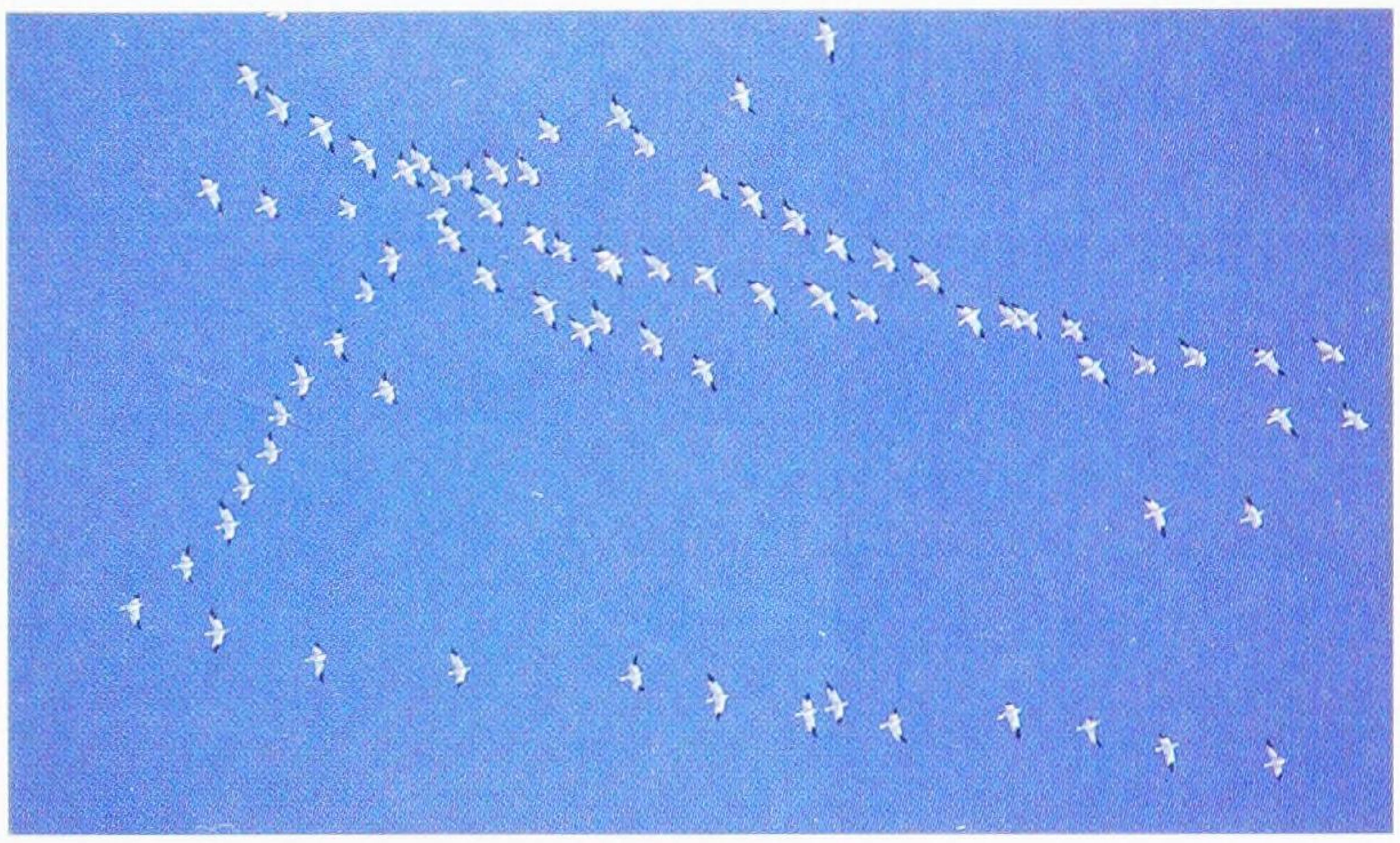


Figure 17-11. Migration is a cyclic behavior.

Cyclic behaviors are innate behaviors that occur in a repeating pattern. They are often repeated in response to changes in the environment. Behavior that is based on a 24-hour cycle is called a **circadian rhythm.** Animals that are active during the day are *diurnal.* Animals that are active at night are *nocturnal.*

Cyclic behaviors also occur over long periods of time. Hibernation is a cyclic response to cold temperatures and limited food supplies. During hiber-

TECHNOLOGY

Looking for a Sign

Young Loulis is learning language from his friends. This hardly seems unusual, except the language is American Sign Language (AMESLAN), and his friends are laboratory chimps.

Scientists have used many different techniques to study the language-learning abilities of nonhuman primates. Most have involved humans teaching apes language, but now some involve letting apes teach other apes. AMESLAN was originally used for studies because apes cannot produce certain human word sounds. AMESLAN is a complete, nonverbal language. Some scientists have made up new languages and have taught apes these.

Apes are using language, creating new words, and teaching these words to other apes. But ape language studies affect humans, too. Yerkish, a symbol language developed for apes, has allowed severely handicapped humans to communicate with others for the first time.

Think Critically: What is the significance of apes, not humans, teaching other apes language?

nation, an animal's body temperature drops to near that of its surroundings, and its breathing rate is greatly reduced. An animal in hibernation survives on stored body fat. The animal remains inactive until the weather becomes warm in the spring. Some mammals and many amphibians and reptiles hibernate.

Have you ever seen large flocks of birds flying overhead in the fall or spring? Many birds and mammals move to new locations when the seasons change instead of hibernating. This instinctive seasonal movement of animals is called **migration.** Many species of birds fly hours or days without stopping. The blackpoll warbler flies nonstop a distance of more than 4000 km from North America to its winter home in South America. The trip takes nearly 90 hours. Arctic terns fly about 17 700 km from their breeding grounds in the Arctic to their winter home in the Antarctic. They return a few months later, traveling a distance of more than 35 000 km in less than a year. Gray whales swim from the cold Arctic waters to the waters off the coast of California. When the young are born, they make the return trip.

Animals have many different behaviors. Some behaviors are innate and some are learned. Many are a combination of innate and learned behaviors. Appropriate behaviors help animals survive, reproduce, and maintain the species.

MINI-Lab

How does an animal enter into hibernation?

Some animals respond to their cold environment by lowering the thermostat of their body. Use the data of a ground squirrel to *graph* this reaction.

Temperature	Hours
37°C	1
25°C	2
30°C	3
15°C	4
14°C	5
13°C	6
10°C	7

Body temperature is maintained between 5°C and 10°C. If the temperature drops below this level, the animal becomes active. How is this helpful?

SECTION REVIEW

1. How do animals communicate?
2. What are some examples of courtship behavior?
3. Give three reasons why animals live in groups.
4. How are cyclic behaviors a response to stimuli in the environment?
5. **Apply:** What behaviors do pet dogs have that indicate they are related to wolves?
6. **Connect to Earth Science:** Find out about a flyway of a migratory bird.

Using Variables, Constants, and Controls

Skill Builder

Design an experiment to show that ants leave chemical trails to show other ants where food can be found. If you need help, refer to Using Variables, Constants, and Controls in the **Skill Handbook** on page 686.

SCIENCE & SOCIETY

17-3 Rehabilitation of Wild Animals

New Science Words

carrying capacity

Objectives

- Explain some of the effects of human development on wildlife.
- Describe the disadvantages of releasing rehabilitated animals into the wild.

Saving Injured Animals

Each year, millions of animals are killed due to the movement of humans into animal territories. Thousands of birds are killed each year after they fly into electrical towers during their night migration. You might have seen wild animals lying along the road after being hit by a car. Thousands of large birds like hawks, owls, and eagles, which prey on other animals, are electrocuted each year while nesting on telephone poles or electric wires.

Many volunteers around the country are working to save animals that have been injured due to human presence. Nursing wild animals back to health is becoming very popular in the United States.

These wild animal rehabilitation programs can be very difficult to conduct. Wild animals are often very uncomfortable out of their natural environment. They require special conditions in order for them to heal and to prevent them from becoming too familiar with their human caretakers. In many rehabilitation programs for birds of prey, the young owls, hawks, or eagles never see their human caretakers. Instead, they are fed by puppets that look very much like their natural parents. By using such puppets to feed them their natural food source, these young have a better chance of surviving on their own later in the wild.

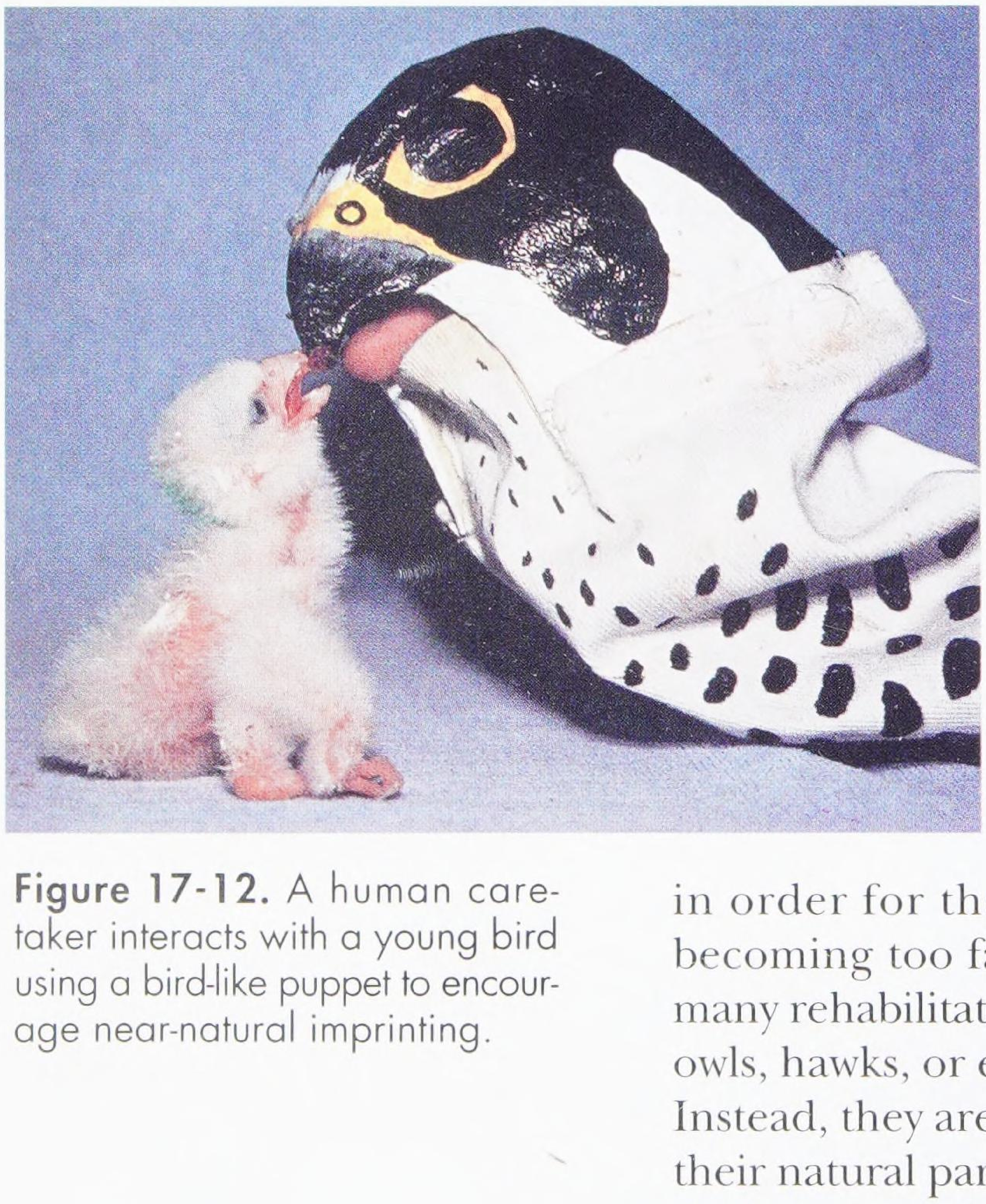


Figure 17-12. A human caretaker interacts with a young bird using a bird-like puppet to encourage near-natural imprinting.

Return to the Wild

Although injured wild animals are often nursed back to good health, some scientists argue that while the individual animal is saved, wild populations do not benefit from releasing rehabilitated animals. We may actually be hurting wild populations by returning these animals to the wild. Through natural selection, the genes of weak individuals are removed from the population to ensure the good health of future generations. Although saving these animals appears to be a very humane venture, the consequences of rehabilitation must be carefully considered. A great deal of research is needed to study the effects of a released animal on its new environment and the effects of the new environment on the animal. Many animals are very territorial. Each territory is designed to hold a certain number of organisms. The number of animals that the environment can support with food and shelter in a given area is called the **carrying capacity.** For example, if an owl was released in a forest that provided only enough resources for the one owl that already lived there, the newly released owl would not survive. Similarly, if the new owl established itself in the forest, the established owl may be forced to leave. In each case, one animal is likely to die due to a lack of resources.

Although rehabilitation appears to be very kind and noble, we must think carefully about its consequences. We must try to reach a balance between our humane instincts and the reality of the natural world.

Connect to... Earth Science

Earth's natural resources, including water, soil, minerals, and living space, are limited. Because these resources are limited, population size of humans and other organisms is limited. How can you help preserve Earth's natural resources?

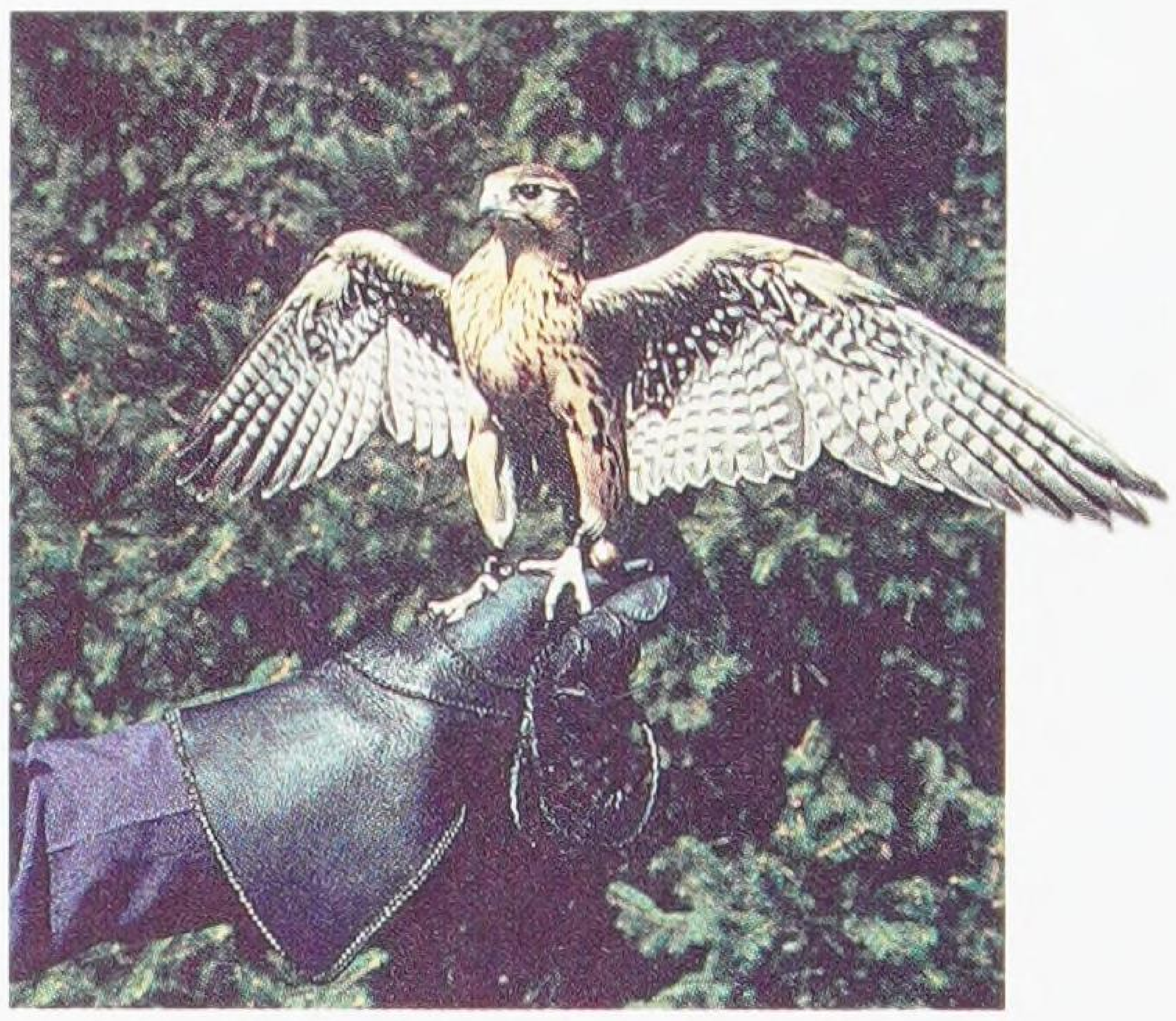


Figure 17-13. A rehabilitated falcon is being released into its natural habitat.

SECTION REVIEW

1. Name three ways in which humans cause injury or death to wild animals.
2. Name two dangers in releasing wild animals into new environments.
3. **Connect to Physics:** Find out why birds are normally not harmed when landing on electric wires.

You Decide!

SCIENCE & SOCIETY

Often during the spring months newly hatched birds are found on the ground after falling out of their nests. Our first tendency may be to help the young bird by bringing it inside and trying to nurse it back to health. Some people might argue that the young bird will serve as food for another animal or for insects. Is it wrong to let nature take its course?

ACTIVITY 17-2

Observing Social Behavior in Ants

Problem: *How do ants live?*

Materials

- 20 ants
- large jar with screen wire cover
- soil
- black paper
- small moist sponge
- water
- food—honey, sugar, bread crumbs
- small can with lid
- spoon or trowel
- hand lens

Procedure

1. Fill the jar 3/4 full with moistened loose soil. Place the damp sponge on top of the soil.
2. Find an ant hill. Use the spoon or trowel to place loose soil from the nest into the small can. Look for ants, small white eggs, cocoons, and larvae. Try to find a queen. The queen will be larger than the other ants. Cover. Place the ants in the refrigerator for a few minutes to slow their movements.
3. Gently place the ants in the jar. Add a small amount of each food in different areas. Place the screen wire cover on the jar.
4. Tape the black paper around the jar. Leave about 2 cm at the top uncovered.
5. Take the paper off for a short period of time each day and *observe* the ants at work. Use a hand lens to observe individual ants.
6. Keep the sponge moistened and add food each day. *Record* your observations each day.

Data and Observations

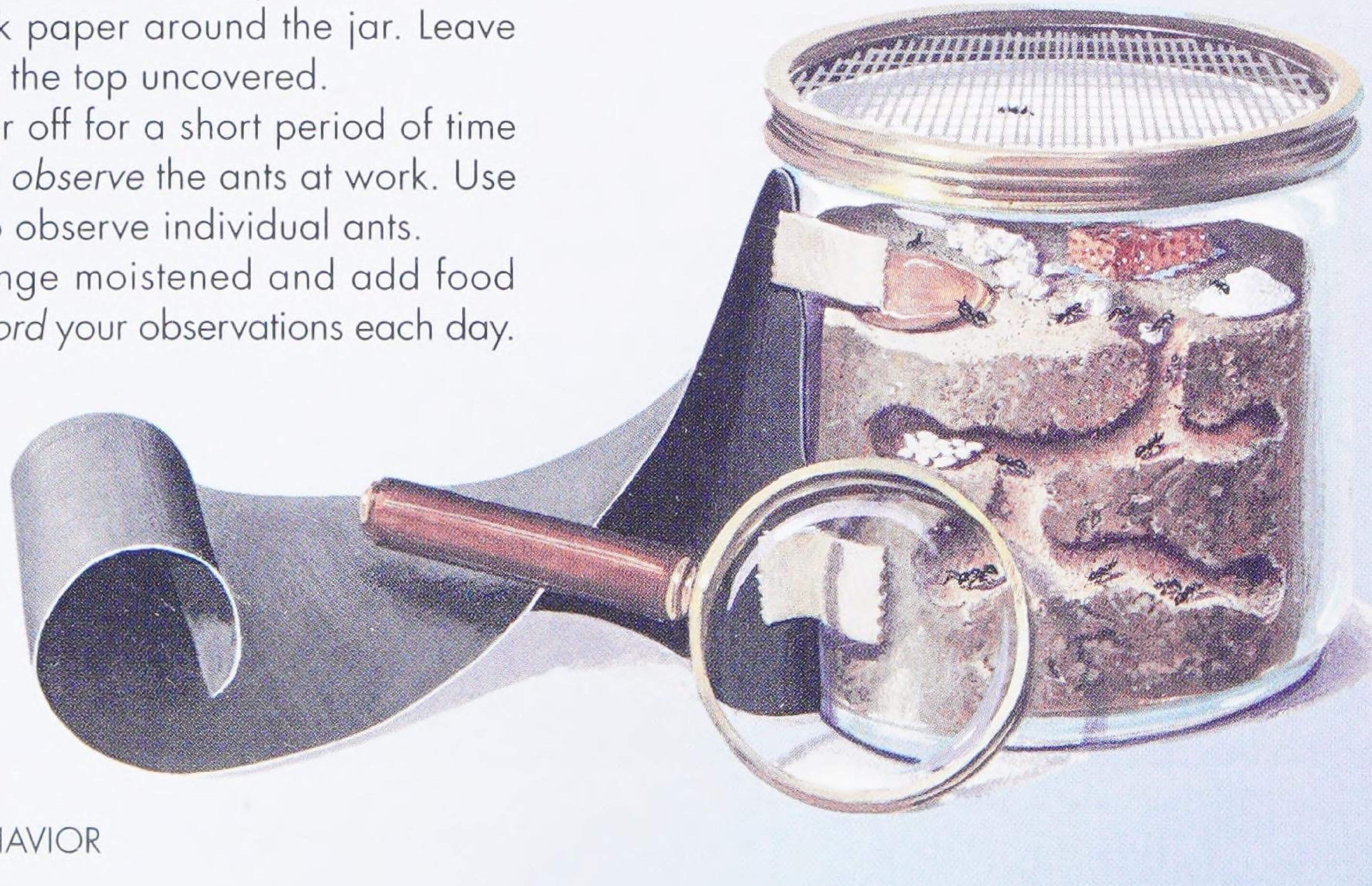
Date	Number of ants visible	Other observations

Analyze

1. How long did it take for the ants to build tunnels after they were placed in the jar?
2. What did you observe that indicated the ants were working together?
3. What kinds of foods do ants prefer?
4. How do the ants in the jar differ?

Conclude and Apply

5. What is a society?
6. What evidence do you have that ants are social insects?



CHAPTER REVIEW

SUMMARY

17-1: Types of Behavior

1. Behavior that an animal is born with is innate behavior. Some animal behaviors are learned. These behaviors are formed through experience.

2. Reflexes are the simplest innate behaviors. An instinct is a complex pattern of innate behavior. A spider spins a web by instinct. Birds build their nests by instinct.

3. Imprinting is a learned behavior in which an animal forms a social attachment to another organism soon after birth. Behavior that is modified by experience is learning by trial and error. Conditioning occurs when a response previously associated with one stimulus becomes associated with another. Insight is a form of reasoning that uses past experiences to solve new problems.

17-2: Behavioral Adaptations

1. Behavioral adaptations such as defense of territory, courtship behavior, and social behavior help species of animals survive and reproduce.

2. Courtship behaviors allow males and females to recognize each other. Courtship behaviors help provide for reproductive success.

3. Interactions among members of the same species are social behaviors. Cyclic behaviors are behaviors that occur in repeating patterns. Cyclic behaviors such as hibernation and migration help animals survive harsh environmental conditions.

17-3: Science and Society: Rehabilitation of Wild Animals

1. Millions of animals are killed or injured each year due to the movement of humans into animal territories. Many animals are hit by cars. Some animals fly into electrical towers, and others are electrocuted while perching on telephone poles or on electric wires.

2. Rehabilitated animals released back into the wild may not be able to find food on their own. The carrying capacity of the environment may also be disturbed by adding these additional animals.

KEY SCIENCE WORDS

a. **aggression**
b. **behavior**
c. **carrying capacity**
d. **circadian rhythm**
e. **communication**
f. **conditioning**
g. **courtship behavior**
h. **cyclic behaviors**
i. **imprinting**
j. **innate behavior**
k. **insight**
l. **instinct**
m. **learning**
n. **migration**
o. **motivation**
p. **reflex**
q. **social behavior**
r. **society**
s. **territory**
t. **trial and error**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. an inherited, not learned behavior
2. automatic response to a stimulus
3. forming a social bond to another organism after birth
4. the way an organism behaves toward its environment
5. change in behavioral response to a given stimulus
6. a defended area
7. using reasoning to solve a problem
8. an organized group of animals in a species
9. behaviors before mating
10. instinctive seasonal movement

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. An example of a reflex is ______.
   - **a.** writing
   - **b.** talking
   - **c.** sneezing
   - **d.** riding a bicycle
2. An instinct is an example of ______.
   - **a.** innate behavior
   - **b.** learned behavior
   - **c.** imprinting
   - **d.** conditioning
3. Nest building is an example of ______.
   - **a.** conditioning
   - **b.** imprinting
   - **c.** learned behavior
   - **d.** an instinct
4. The animals that depend least on instinct and more on learning are ______.
   - **a.** birds
   - **b.** fish
   - **c.** mammals
   - **d.** amphibians
5. ______ involves using reasoning to solve problems.
   - **a.** Insight
   - **b.** Imprinting
   - **c.** Conditioning
   - **d.** Trial and error
6. Something inside an animal that causes the animal to act is ______.
   - **a.** conditioning
   - **b.** imprinting
   - **c.** insight
   - **d.** motivation
7. Teeth, beaks, and claws are used for ______.
   - **a.** killing prey
   - **b.** fighting
   - **c.** hurting other birds
   - **d.** sending signals
8. All are examples of courtship behavior except ______.
   - **a.** fluffing feathers
   - **b.** taking over a perch
   - **c.** singing songs
   - **d.** releasing pheromones
9. An organized group of animals working specific jobs is a ______.
   - **a.** community
   - **b.** territory
   - **c.** society
   - **d.** circadian rhythm
10. The response of inactivity and slowed metabolism that occurs during cold conditions is ______.
    - **a.** hibernation
    - **b.** imprinting
    - **c.** migration
    - **d.** circadian rhythm

USING LAB SKILLS

11. In Activity 17-1, you learned how to condition fish. Based on your observations, design an experiment to show how you could condition your dog to return a ball or frisbee to you. Carry out your experiment.
12. Repeat Activity 17-2 using different food types: aspartame (a sugar-substitute), apple pieces or molasses. Compare your observations with those made in your original laboratory activity.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. What is the advantage of living in a group?
14. What are the advantages of reflex behaviors?
15. Give an example of something you learned by trial and error.
16. Describe the ways territoriality is expressed to other members of the species.
17. Compare conditioning, trial and error, and imprinting using examples of each.

APPLY

18. Explain the type of behavior involved when the bell rings at the end of class.

19. Discuss the advantages and disadvantages of migration as a means of survival.

20. Explain how a habit, such as tying your shoes, is different from a reflex.

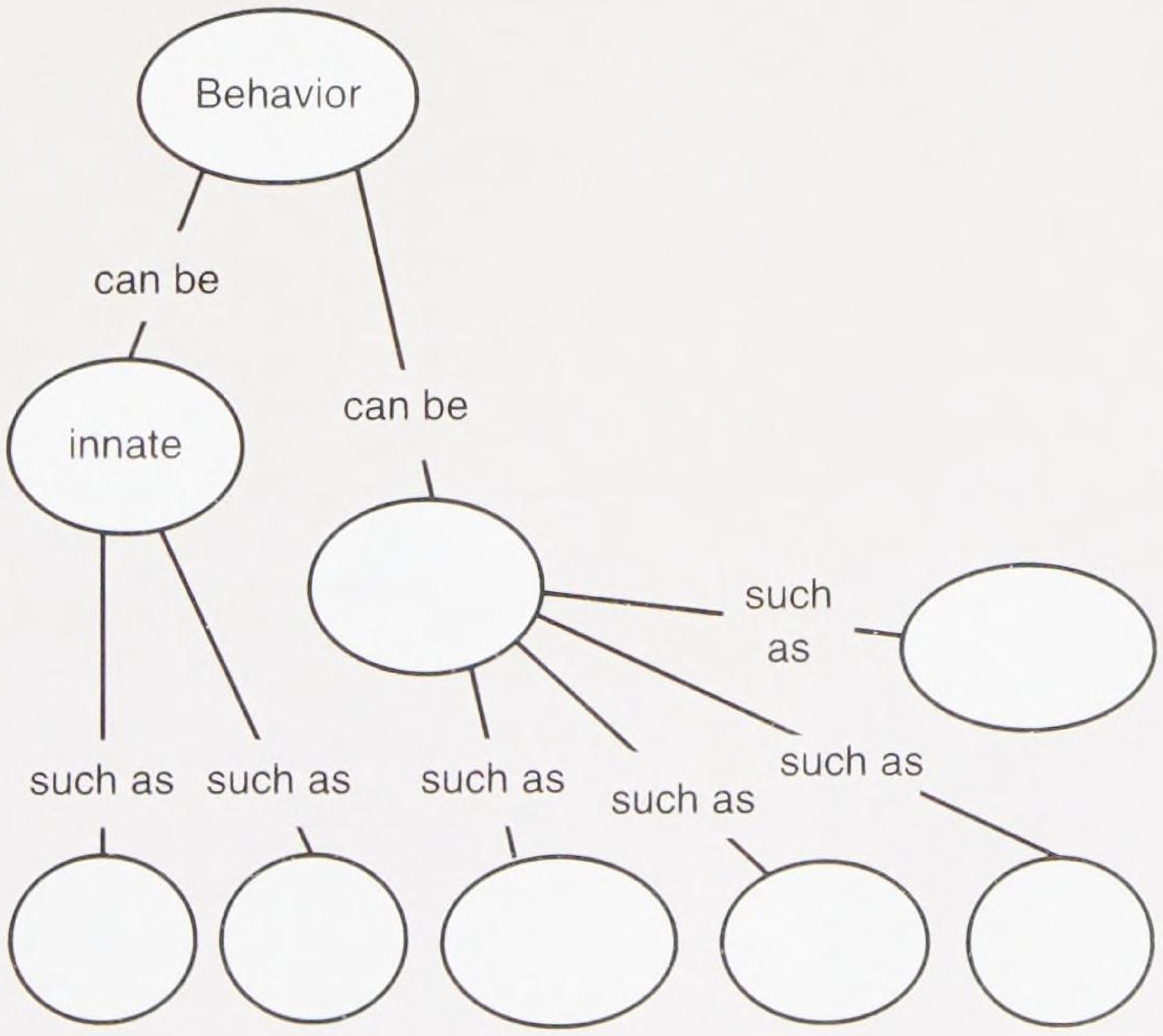
21. Use one example to explain how behavior increases an animal's chance for survival.

22. Hens lay more eggs in the spring when day length increases. How can farmers use this knowledge of behavior to their advantage?

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Classifying:** Make a list of 25 things that you do regularly. Classify each as an innate or learned behavior. Which behaviors do you have more of?
2. **Concept Mapping:** Complete the following concept map outlining the types of behavior.



3. **Observing and Inferring:** Make observations of a dog, cat, or bird for a week. Record what you see. How did the animal communicate with other animals and with you?
4. **Using Variables, Constants, and Controls:** Design an experiment to get a specific response to a stimulus by an animal.
5. **Hypothesizing:** Make a hypothesis about how frogs commmunicate with each other. How could you test your hypothesis?

PROJECTS

1. View the film *Never Cry Wolf* (Disney). Write a summary of the behaviors of the wolves.
2. Draw a map showing the migration route of caribou, the gray whale, or arctic wolf.

UNIT 5

GLOBAL CONNECTIONS

Animals

In this unit, you have studied a variety of animals. Now find out how animals are connected to other subjects in different parts of the world.

OCEANOGRAPHY

AN INVASION OF THE U.S. MAINLAND

Lake St. Clair, Michigan

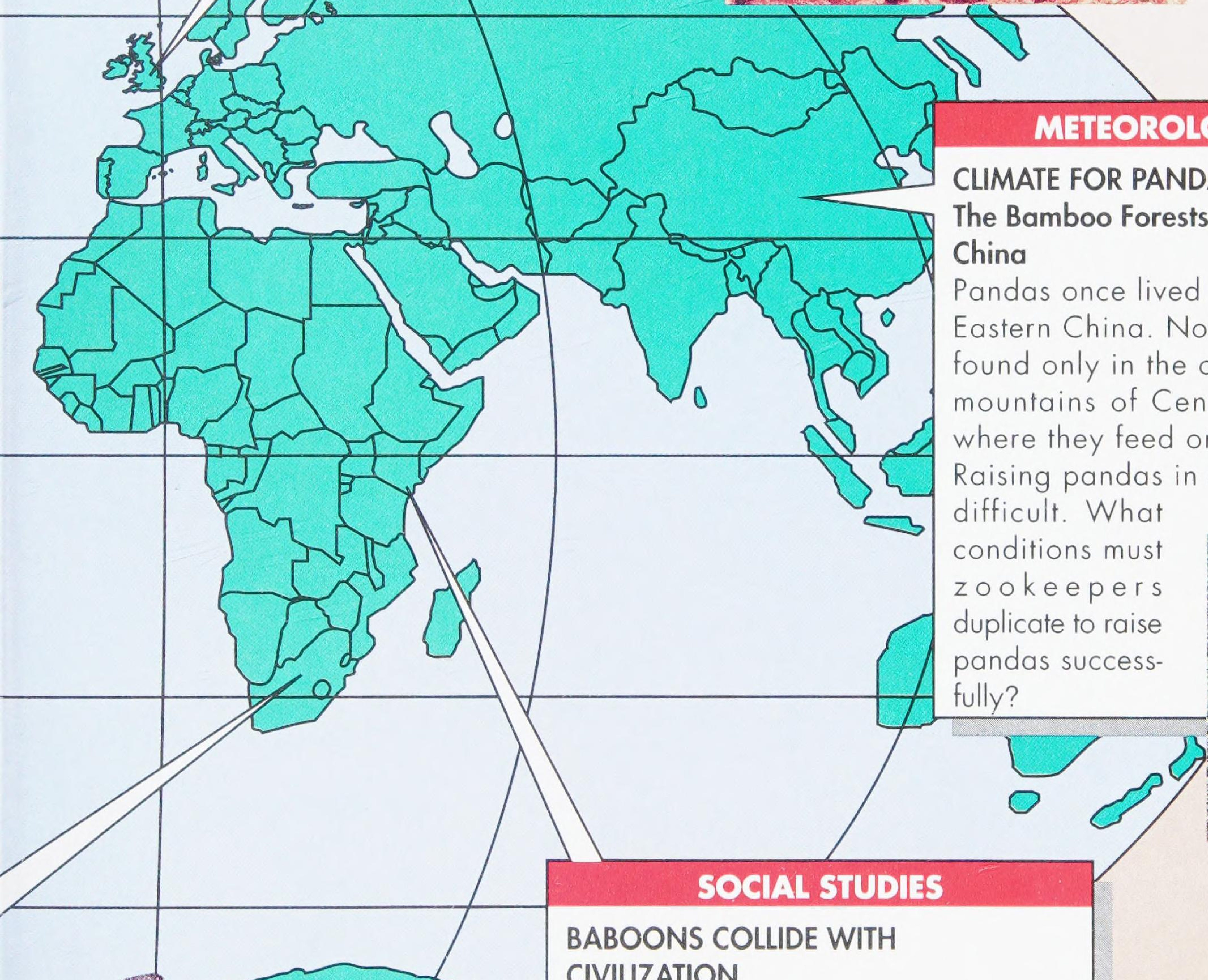
They look insignificant, but zebra mollusks are threatening city water systems and beaches along the Great Lakes. They have few natural predators. Why have zebra mollusks become so abundant? Suggest some ways that zebra mollusks might be controlled.

GEOGRAPHY

ADVENTURES WITH BLACK EAGLES

Pretoria, South Africa

Largest of all the eagles, black eagles inhabit the wild highlands of Southeast Africa. Their enemies are fire, drought, and sheep farmers. Why would fire and drought be a problem for the eagles?

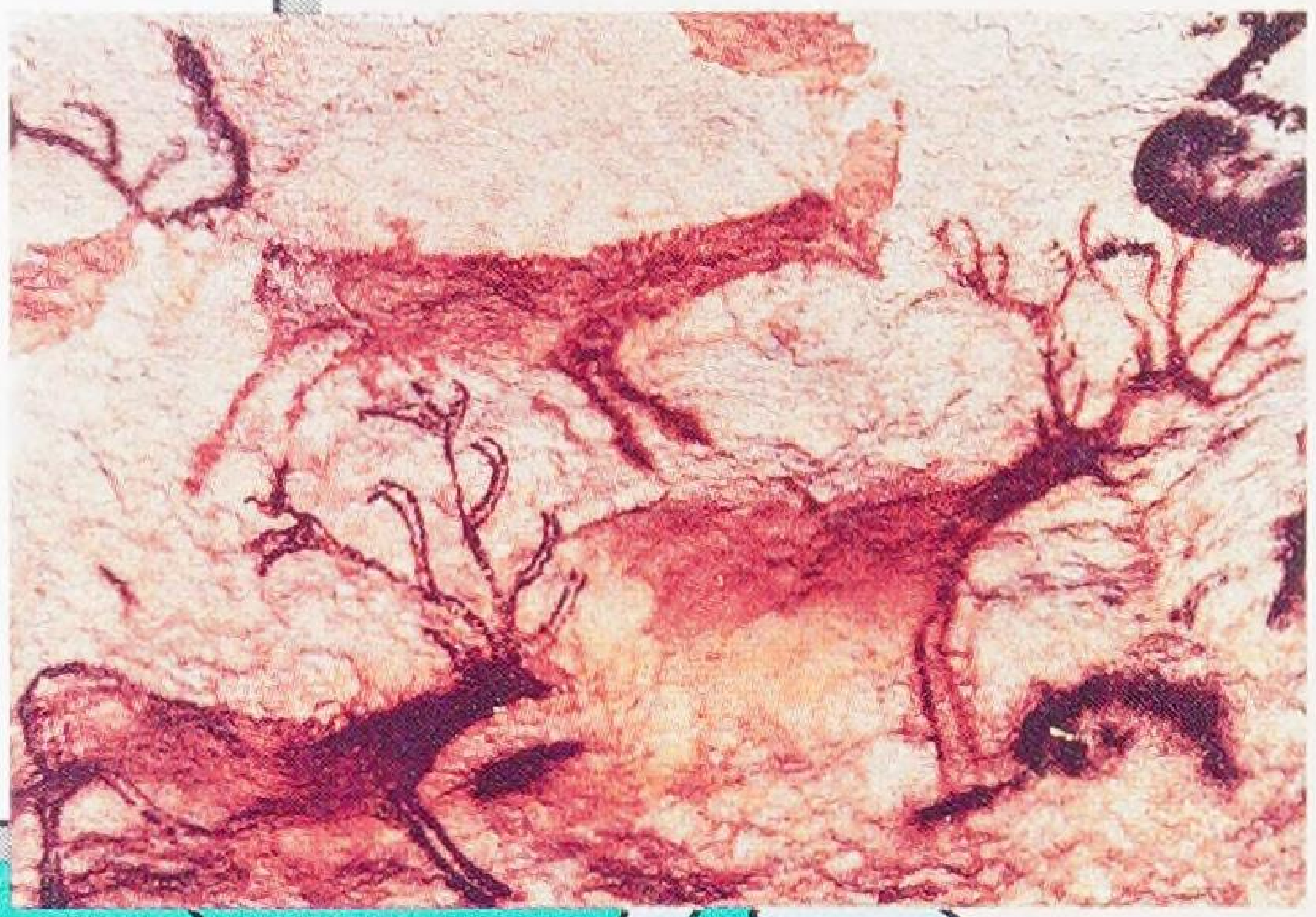


HISTORY

EUROPE'S RED DEER, A LEFT-OVER FROM THE ICE AGE

Devon, England

Drawings of red deer that were made 15 000 years ago appear on the walls of Stone-Age caves. The deer are still hunted in England today. Game biologists support deer hunting. Why do you think they do?



METEOROLOGY

CLIMATE FOR PANDAS

The Bamboo Forests of Central China

Pandas once lived in much of Eastern China. Now they are found only in the chill, damp mountains of Central China where they feed on bamboo. Raising pandas in captivity is difficult. What conditions must zookeepers duplicate to raise pandas successfully?

SOCIAL STUDIES

BABOONS COLLIDE WITH CIVILIZATION

Nairobi, Kenya

Kekopey Ranch was being settled, but there was no room for the troop of baboons who already lived there. Moving them was risky. What conditions will the baboons need in their new environment?

CAREERS

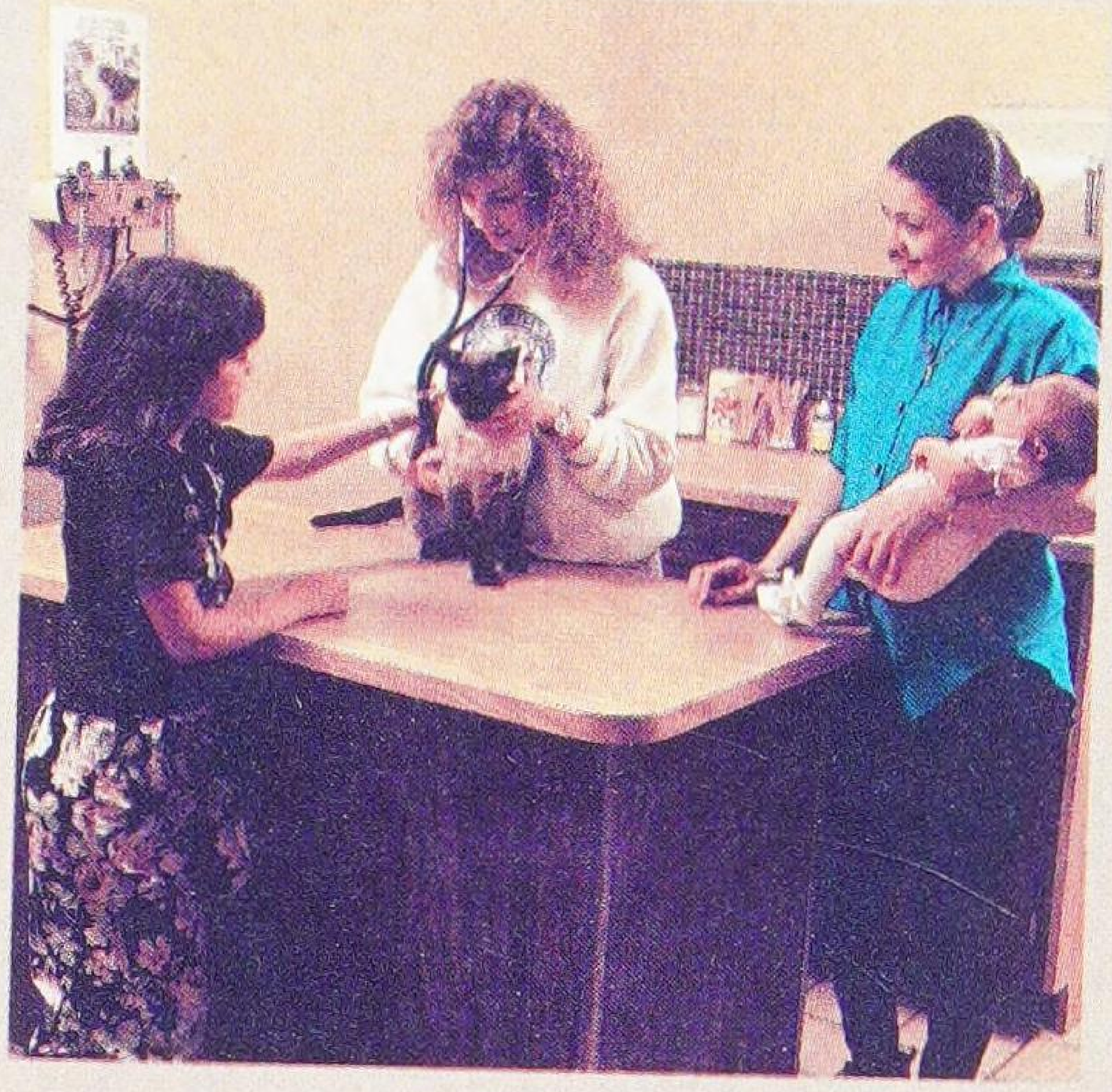
ZOOLOGIST

A *zoologist* is a scientist who studies animals. These scientists are interested in the animal's habitat, behavior, diseases, and life processes. Zoologists who study birds are called ornithologists. Those who study reptiles are called herpetologists. Mammalogists study mammals and ichthyologists study fish.

A person who wants to become a zoologist should like working with animals and be willing to spend long and irregular hours with them. Zoologists need a background in science, particularly biology, zoology, and animal behavior. A trained zoologist will need to have a bachelor of science degree for non-research work. If they plan to do research, they will need to have a master's degree.

For Additional Information

Contact the American Society of Zoologists, 104 Sirius Circle, Thousand Oaks, CA 91360.



VETERINARIAN'S TECHNICIAN

A *veterinarian's technician* likes animals and enjoys working with them. He or she should be calm and reliable, as well as willing to work hard. Some of the work that veterinarian's technicians do is not easy. Cages have to be cleaned, animals groomed, and excited animals must be calmed. Most veterinary technicians are trained on the job. It is possible to start as a part-time animal attendant and advance to technician. Experienced technicians may also find work in kennels, small zoos, pet stores, as assistant laboratory animal technicians, or with the Humane Society.

Some veterinarian technicians want to open their own kennels to raise, groom, or board small animals.

For Additional Information

Contact Animal Caretakers Information, The Humane Society of the U.S., Companion Animals Division, Suite 100, 5430 Grosvenor Lane, Bethesda, MD 20814.

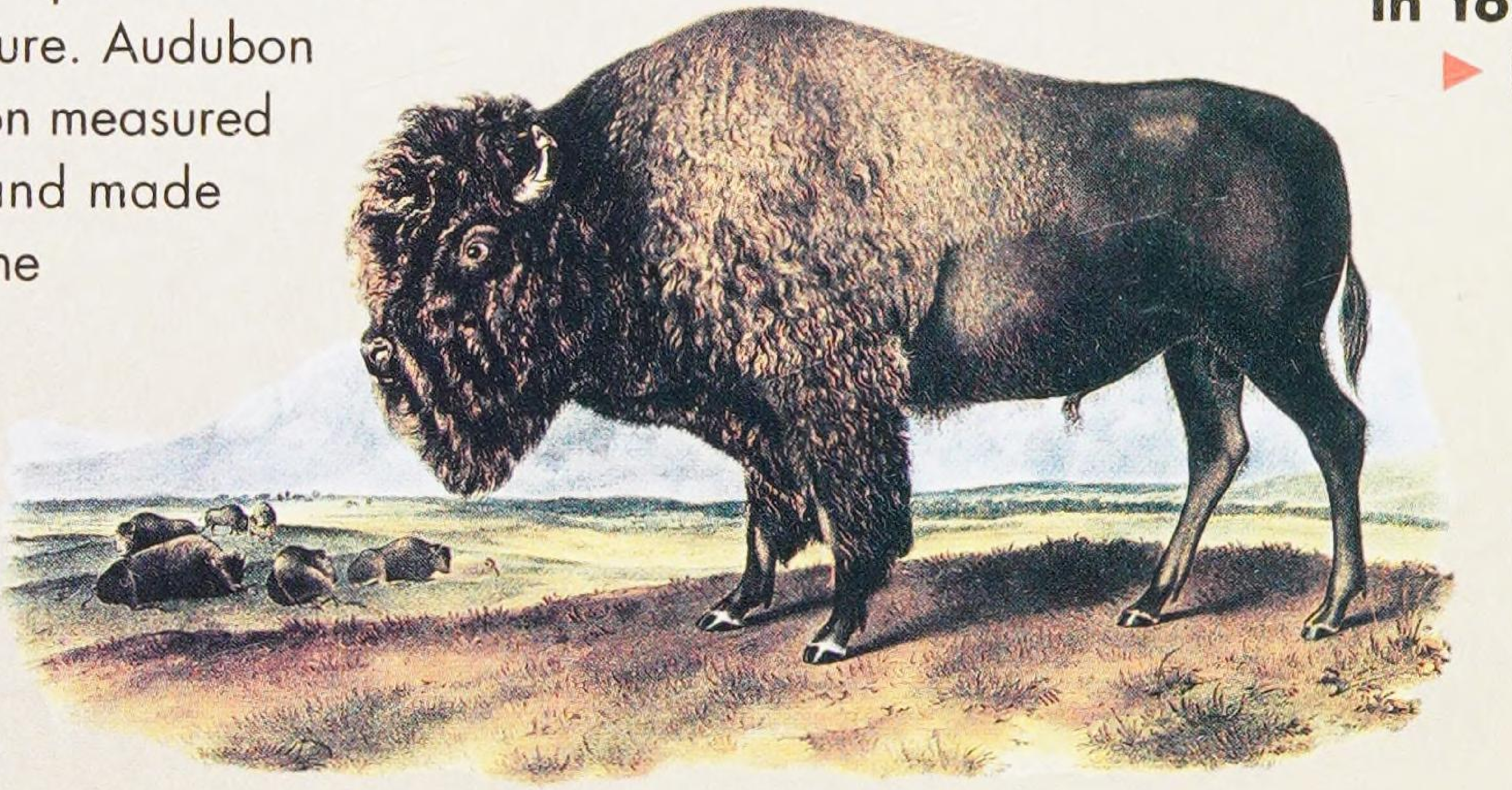
UNIT READINGS

- ▶"Zebras Are Coming." *Popular Mechanics,* February 1991.
- ▶Schaller, George G. "Pandas in the Wild." *National Geographic,* December 1981.
- ▶Clutton-Brock, T.H., "Red Deer and Man." *National Geographic,* October 1986.

John James Audubon
The American Bison

Many people know of Audubon's beautiful bird paintings. In fact, Audubon's birds are what he is best known for today. But Audubon painted other animals, or quadrupeds, as he called them. This painting of the American bison was done in 1845 during a trip Audubon made to the Dakota Prairies.

Audubon did this painting of a male bison. As you study it, you will notice that the painting is so carefully done, it seems almost like a photograph. All attempts were made to be true to nature. Audubon had a dead bison measured and weighed, and made careful notes of the measurements. The painting was one seventh the original size of the animal.



Drawing birds and wild animals was the only thing that made Audubon really happy. Born in Haiti, he spent his early years in France before going to America at 18. His father, a wealthy French planter, tried to set him up in business, but Audubon failed miserably because he was, as a business partner said, continually in the forest. To develop detailed paintings of birds, he used dead birds in their natural settings as his models. In 1826, he began to publish volumes of his works on North American birds. By 1845, Audubon had sold a series of subscriptions for his bird paintings throughout Europe and America. The work had taken him over twenty years to produce.

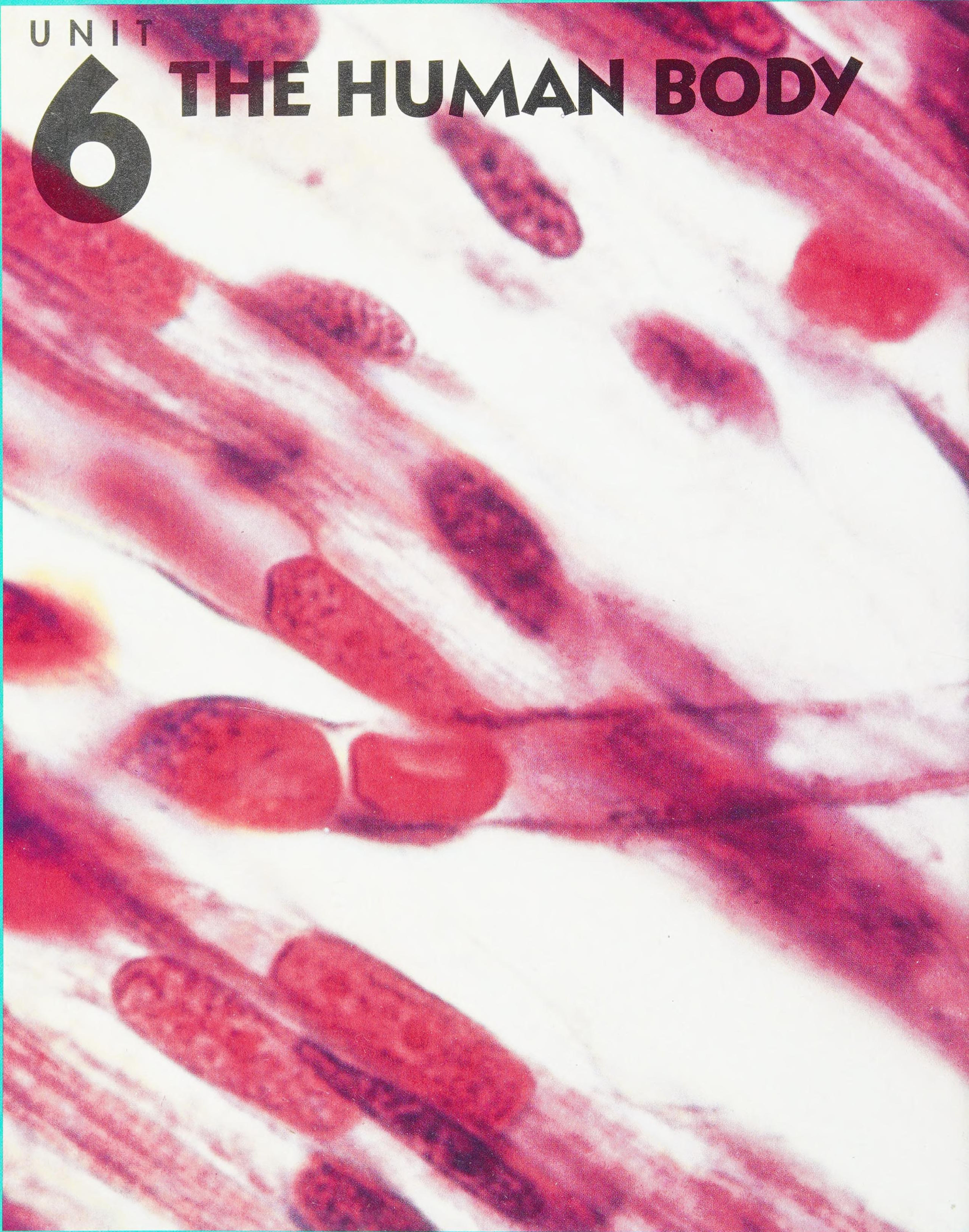
Now he wanted to complete a series of quadrupeds as well. But he was 53 years old and losing his memory. Only 150 prints of animals were ever completed. Audubon was deeply saddened by the killing of bison and wrote of a hunt he had seen, "What a terrible destruction of life, as it were for nothing, or next to nothing....."

In Your Own Words

- Investigate an extinct or endangered species of North American animal. Describe the animal and how it became endangered or extinct. Illustrate the animal in some way.

UNIT

6 THE HUMAN BODY



What's Happening Here?

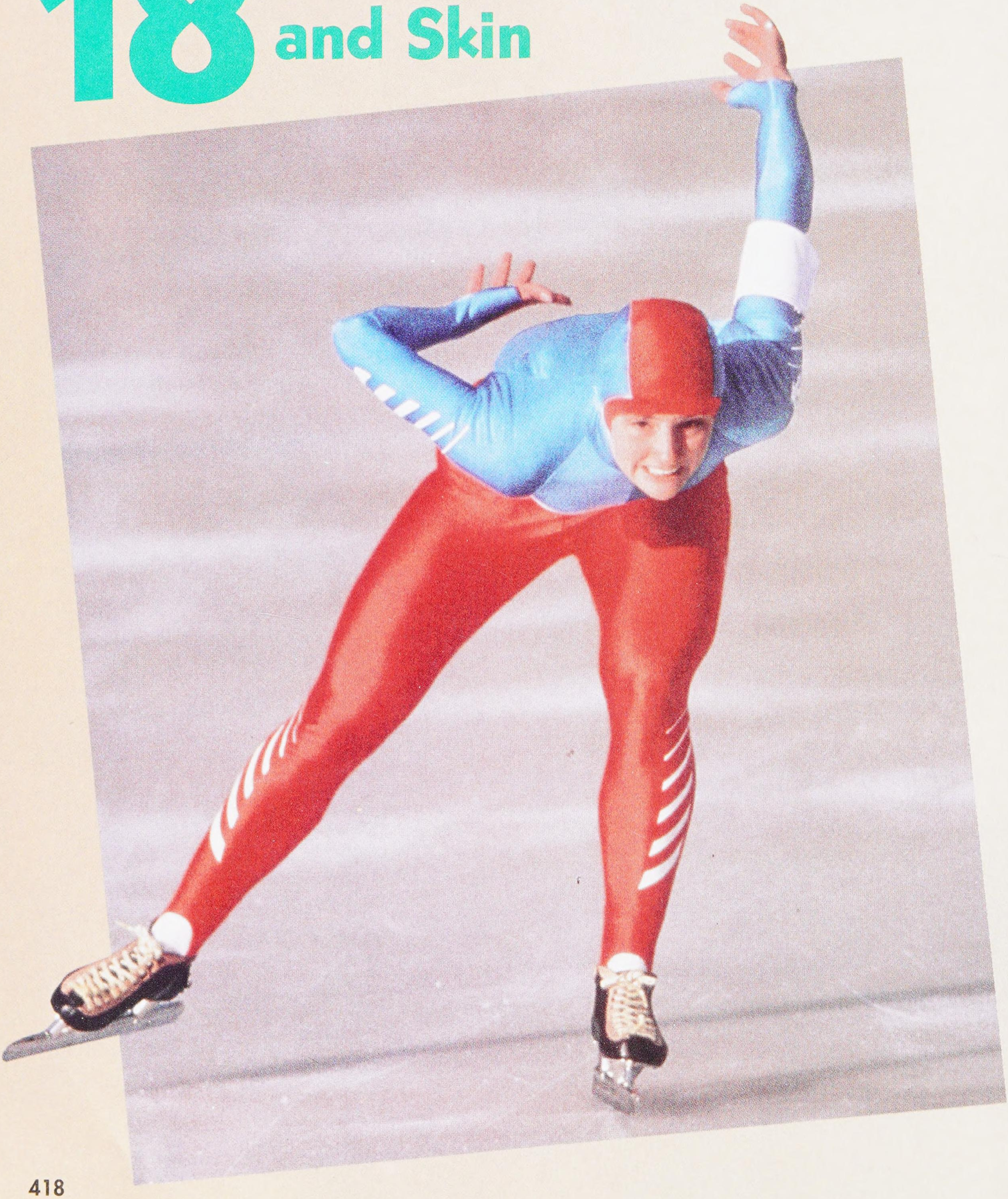
Blood surges through your blood vessels with every beat of your heart. Red blood cells carrying oxygen bend and contort as they are pushed through narrow capillaries. White blood cells tumble past in the river of plasma, on their way to the day-to-day work of keeping you healthy. A ride through a water slide may give you an idea of what it is like to be a blood cell on this journey. In this unit, you will learn about your circulatory system. You will also learn about the other body systems on which your life depends.

UNIT CONTENTS

Chapter 18 Bones, Muscles, and Skin
Chapter 19 Nutrients and Digestion
Chapter 20 Your Circulatory System
Chapter 21 Respiration and Excretion
Chapter 22 Body Regulation
Chapter 23 Reproduction and Growth

CHAPTER

18 Bones, Muscles, and Skin



Like the speed skater on the left, you might have experienced tired muscles after gym class or a soccer game. Although large muscles are the ones that you notice when they tire, your body has many small muscles that can tire after just a little bit of work.

FIND OUT!

Do this activity to find out about some of your small muscles.

Hold a snap-type clothespin between the thumb and forefinger of your writing hand. Rapidly pinch the clothespin open and shut. Count the number of times you can pinch the clothespin before the fingers in your hand become tired. *Record* the number. Use the thumb and forefinger of your other hand. How do they compare? Do small muscles that are exercised more (your writing hand) tire faster or slower than those in the hand that gets less exercise?

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 18-1 The Skeletal System
- What Is a Skeletal System?
- Bone
- Bone Development
- Fractures
- Joints

Section 18-2 The Muscular System
- The Muscular System
- Three Types of Muscle Tissue
- Muscles at Work

Section 18-3 Science and Society
Drugs for Fitness?
- Do Steroids Give a "Winning Edge"?

Section 18-4 Skin
- The Body's Largest Organ
- Skin at Work

Previewing Science Skills

- In the **Skill Builders,** you will outline, sequence, and make a concept map.
- In the **Activities,** you will observe, collect data, hypothesize, and experiment.
- In the **MINI-Labs,** you will observe and experiment.

What's next?

Throughout the day, hundreds of muscles, both large and small, work to move your body. In this chapter, you'll learn how muscles and bones provide the body with a working structure. You'll also learn about skin, your body's largest organ, and its many functions.

18-1 The Skeletal System

New Science Words

skeletal system
periosteum
marrow
cartilage
fracture
joint
ligament
immovable joint
movable joint

Objectives

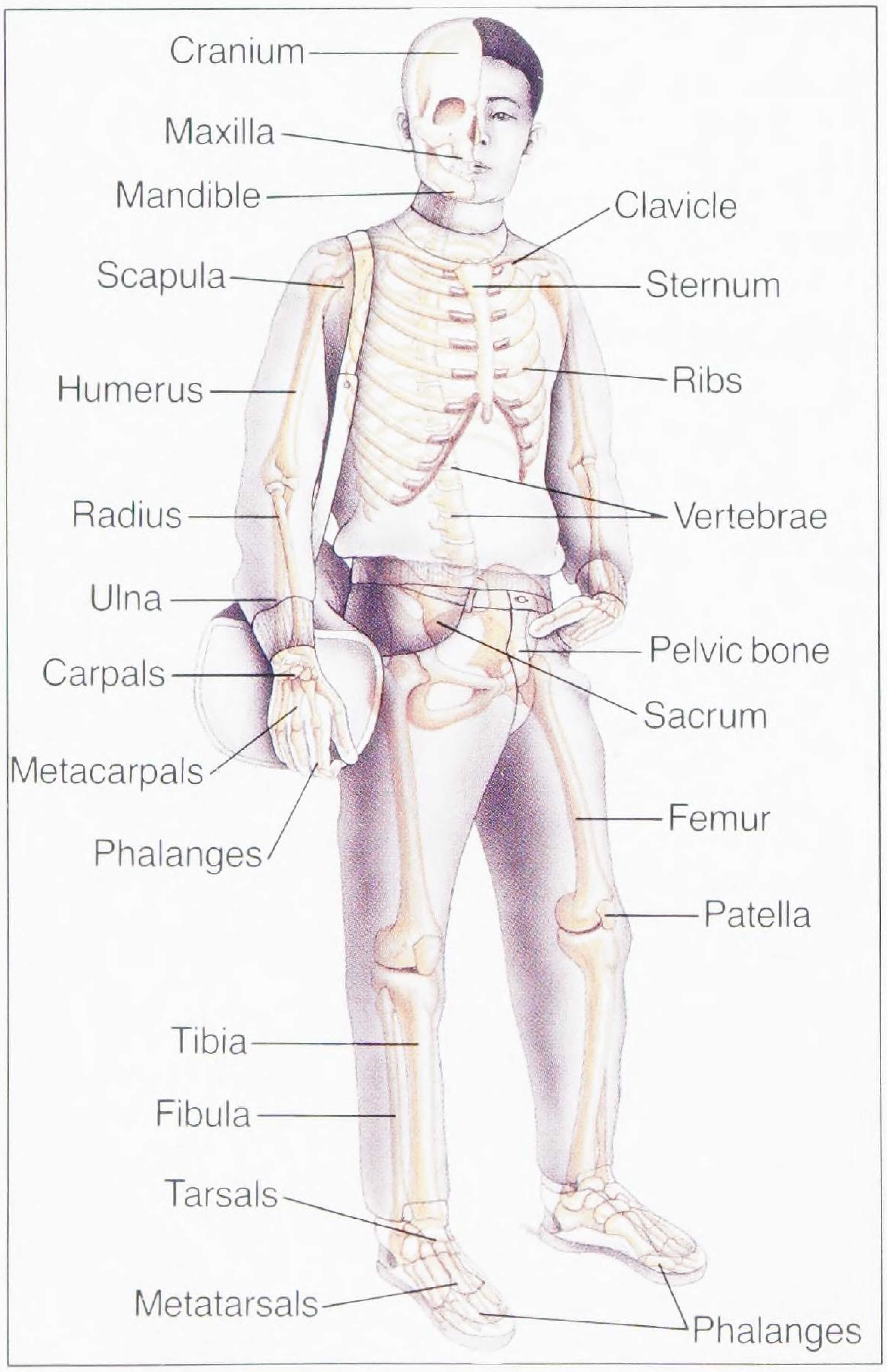
- Identify the five major functions of the skeletal system.
- Describe how a fracture heals.
- Compare and contrast movable and immovable joints.

What Is a Skeletal System?

Does the doctor you go to have a human skeleton in the office? If so, you might have the impression that all bones are dead structures made of dry, rocklike material. It's true that the skeleton's bones are no longer living, but the bones in your body are very much alive. Each bone within your body is a living organ made of several different tissues. Cells in these bones take in food and expend energy. They have the same requirements as other cells in your body.

Because you have a skeleton, you stand, walk, run, and breathe. All the bones together make up your **skeletal system,** which is the framework of your body. The human skeletal system has five major functions. First, it gives shape and support to your body, much like the framework of a building. Second, bones protect your internal organs. In the skeleton shown in Figure 18-1, ribs surround the heart and lungs with a bony cage, and a hard skull encloses the brain. Third, major muscles of the body are attached to bone. Muscles move bones. Fourth, blood cells are formed in the red marrow of some bones. Bone marrow is a soft tissue in the center of the many bones. Finally, the skeleton is the place where major quantities of calcium and phosphorus compounds are stored for later use in the body. Calcium and phosphorus make bone hard.

Figure 18-1. The Human Skeletal System


Cranium
Maxilla
Mandible
Clavicle
Scapula
Sternum
Humerus
Ribs
Radius
Vertebrae
Ulna
Pelvic bone
Carpals
Sacrum
Metacarpals
Femur
Phalanges
Patella
Tibia
Fibula
Tarsals
Metatarsals
Phalanges

Bone

Pick up a bone and you'll find that it isn't all smooth. There are bumps, edges, round ends, rough spots, and many pits and holes. Each of these marks has a purpose. Muscles attach to some of the bumps and pits. Blood vessels and nerves enter and leave through the holes.

Your skeleton has 206 bones of various sizes and shapes. Bones are frequently classified according to shape. Figure 18-2 shows bones that are long, short, flat, or irregular. Their shapes are genetically controlled and modified by the work of muscles attached to them.

Many internal and external characteristics of bone are easily seen in the humerus shown in Figure 18-3. The humerus is a long bone in your upper arm. The surface of the long portion of the bone is covered with a tough, tight-fitting membrane called **periosteum** (per ee AHS tee um). Small blood vessels in the periosteum carry nutrients into the bone. This membrane is also important in the growth and repair of bone. Under the periosteum is compact bone, a hard, strong layer of bone. Compact bone contains bone cells, blood vessels, the minerals calcium and phosphorus, and elastic fibers. Rickets and osteoporosis are two diseases that result from lack of minerals in bone. Elastic fibers keep bone from being too rigid and brittle or easily broken.

Spongy bone in a long bone is found toward the ends of the bone. Spongy bone is much less compact and has many small open spaces that make the bone lightweight. If all your bones were completely solid, you'd have a much greater mass. Long bones have large openings, or cavities. The cavities in the center of long bones and the

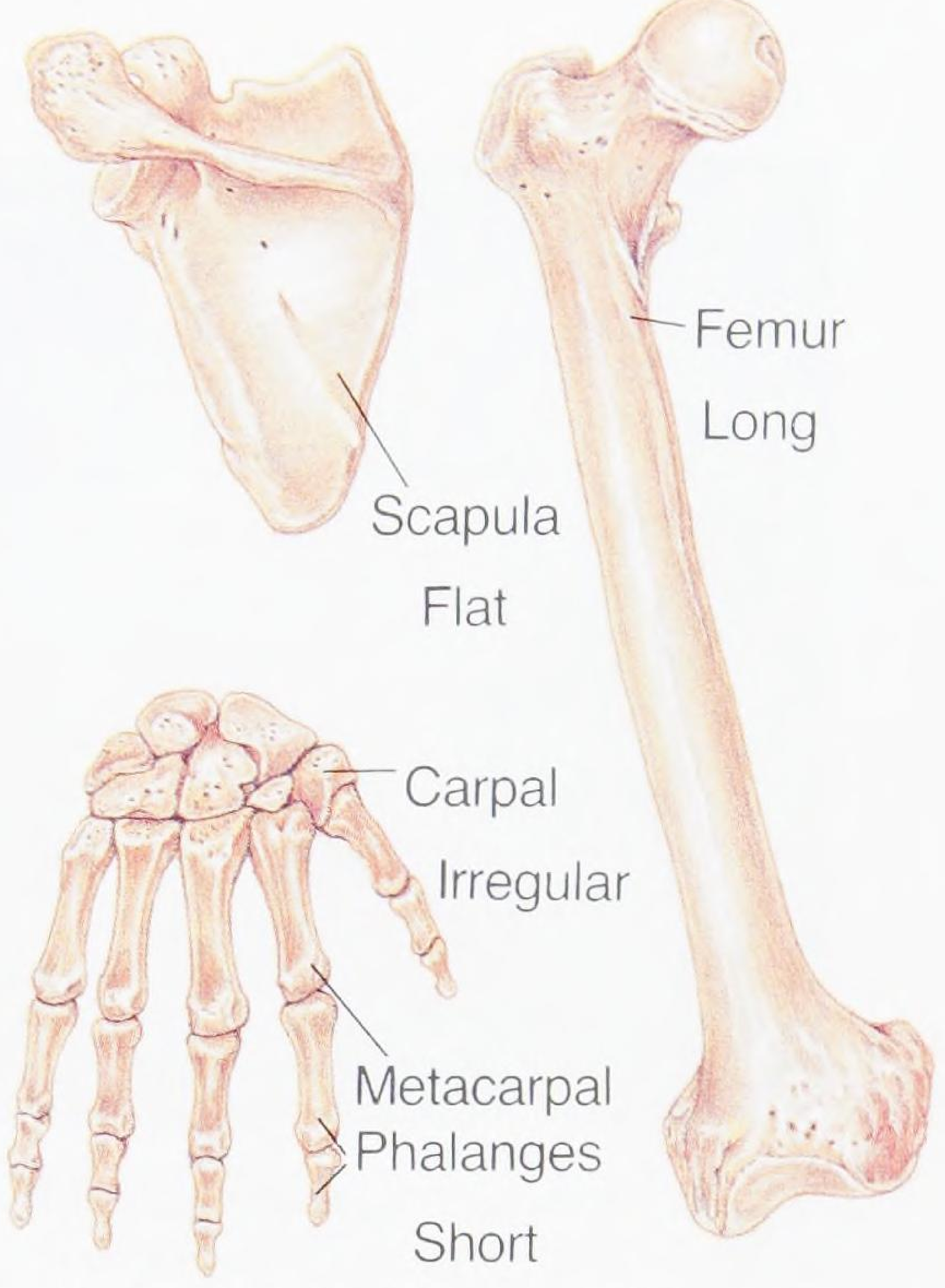
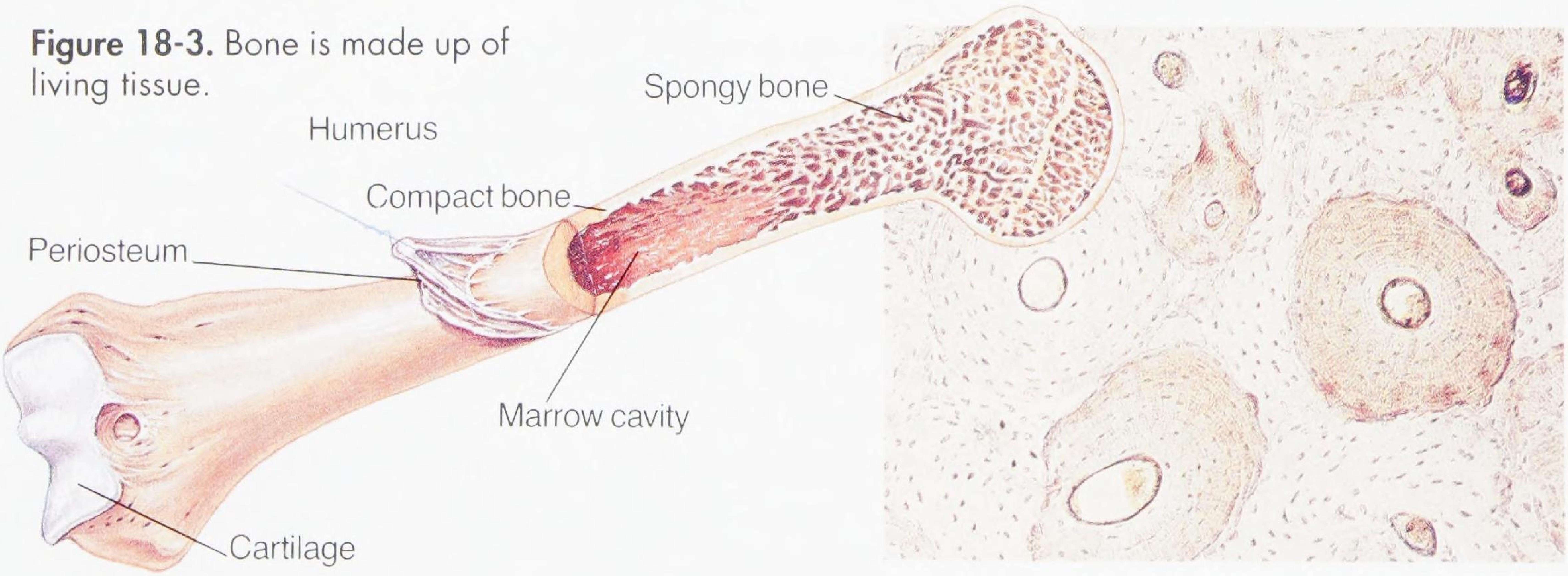


Figure 18-2. Shapes of human bones show something about their functions.

Connect to... Earth Science

One of the minerals found in bone is calcium carbonate. This compound makes up 3.6 percent of Earth's crust. Find out the relationship between calcium carbonate and limestone. What is limestone formed from?

Figure 18-3. Bone is made up of living tissue.



spaces in spongy bone are filled with a fatty tissue called **marrow.** In a healthy person, marrow produces red blood cells at an incredible rate of between two and three billion cells per second. White blood cells are also produced in bone marrow, but in lesser amounts.

Unless you have a condition called arthritis, you move about fairly comfortably. This is because the ends of your bones are covered with a thick, smooth layer of tissue called **cartilage.** Cartilage does not contain blood vessels or minerals. It is flexible and is important at joints, where it absorbs shock and makes movement easier.

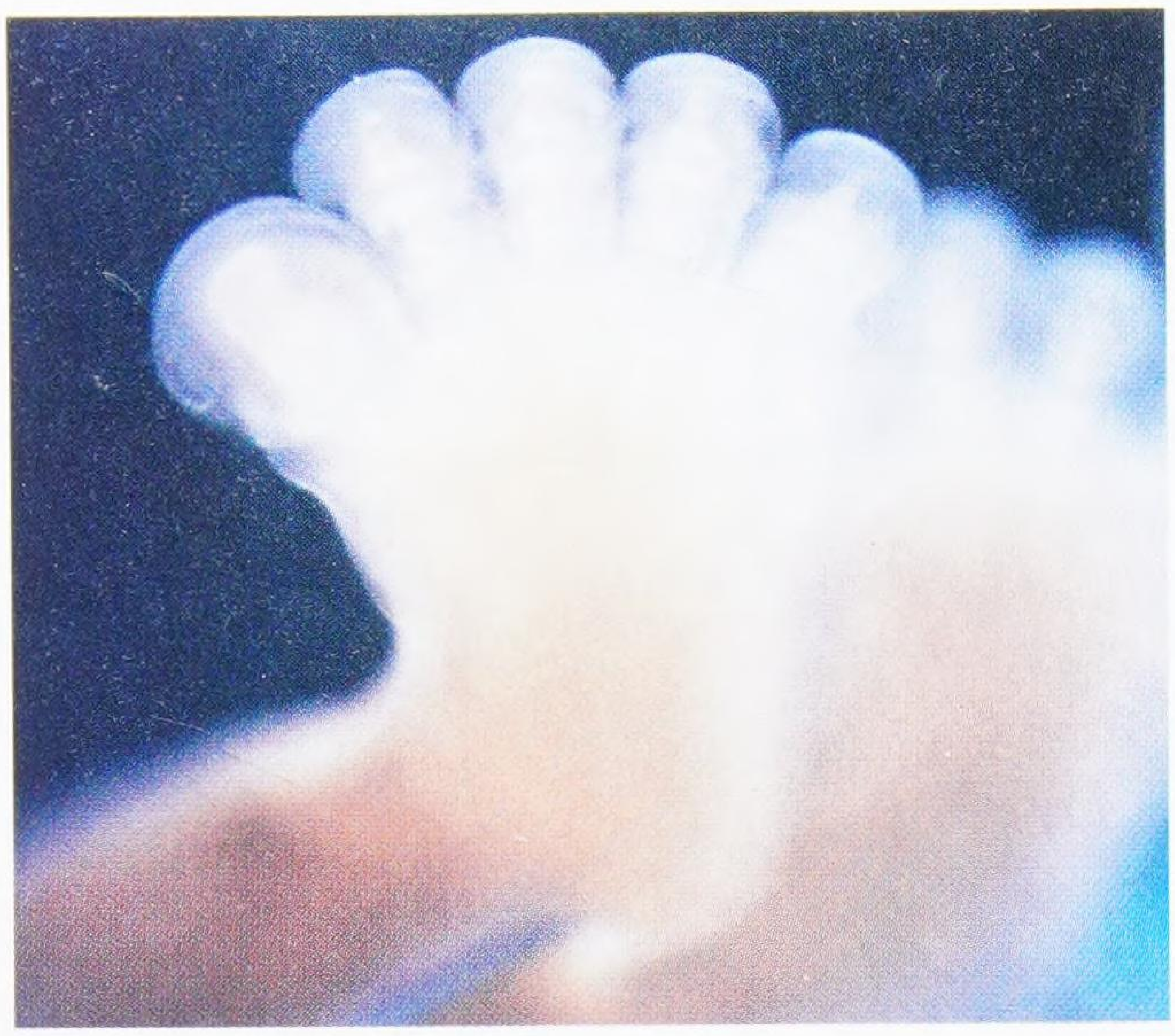


Figure 18-4. During development before birth, the skeleton is first made up of cartilage, which is then gradually replaced by bone.

Bone Development

Before you were born, your skeleton was first made in the form of cartilage. Gradually the cartilage was broken down and replaced by bone-forming cells called osteoblasts (AHS tee oh blastz). These cells deposit calcium and phosphorus that make bone tissue hard. At birth, your skeleton was made up of more than the 206 bones you now have. As you developed, some bones fused, or grew together.

How is bone formed and reformed?

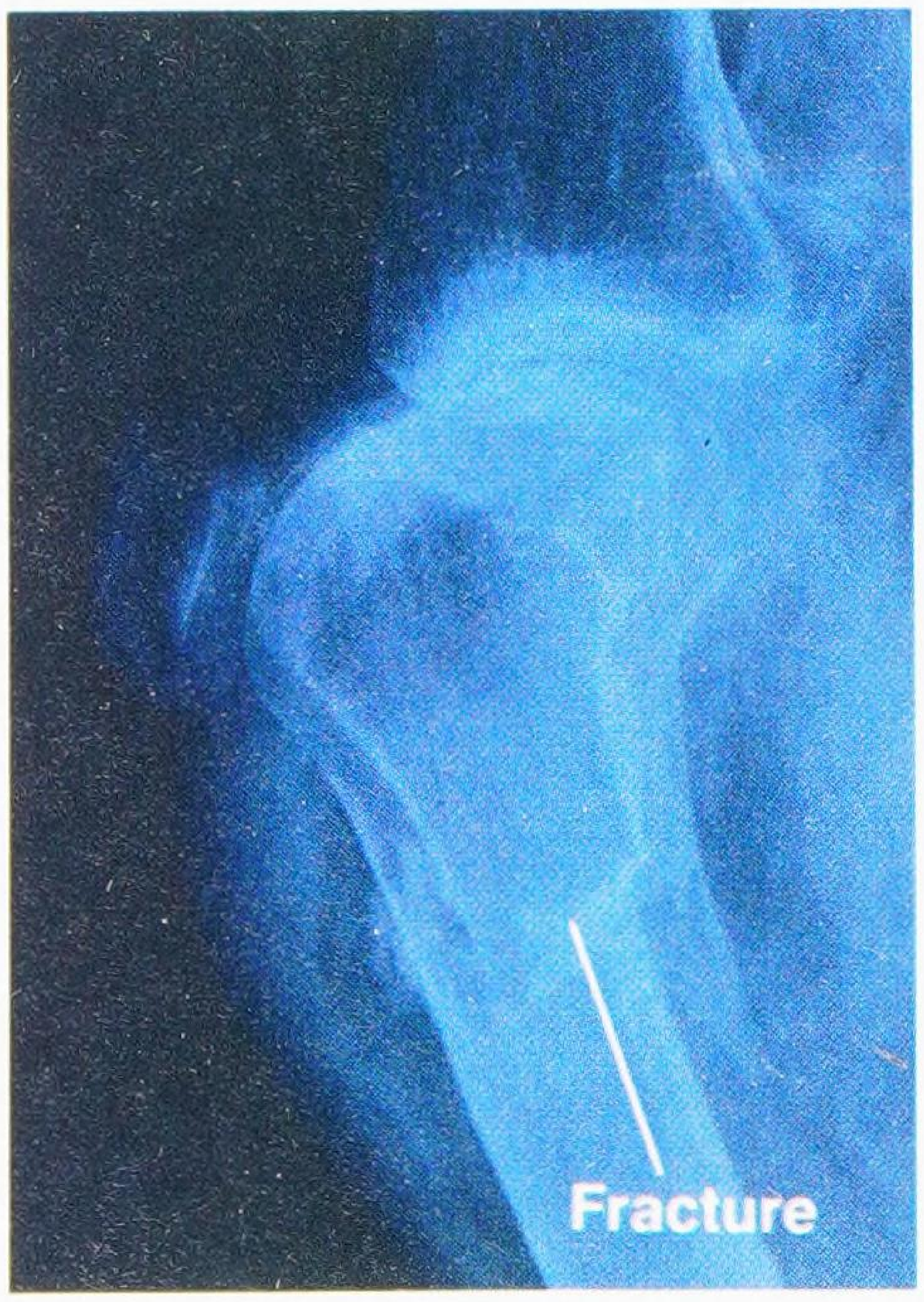
Healthy bone tissue is dynamic. It is always being formed and reformed by the cells it contains. A second type of bone cell, an osteoclast, breaks down bone tissue. This is a normal process in a healthy person. Osteoclasts break down bone and release calcium and phosphorus. This process keeps the calcium and phosphorus in your bloodstream at about the same level.

Fractures

Although bones are strong and flexible, they can break. A break in a bone is a **fracture.** A simple fracture occurs when a bone has broken but the broken ends do not break through the skin. In a compound fracture, the broken ends of the bone stick out through the skin.

To heal, the broken ends of the bone have to be brought in contact with each another. The periosteum starts to make new bone cells. A thick band of new bone forms around the break, acting like a built-in splint. Over time, the thickened band disappears as bone is reshaped with the help of osteoclasts. Breaks are usually held immobile with a cast.

Figure 18-5. For a fracture to heal, the broken ends of the bone have to be brought together.



Joints

Think of all the different actions you performed this morning getting ready for school. You opened your mouth to yawn, chewed your breakfast, reached for a toothbrush, and stretched out your arm to turn the doorknob as you walked out the door. All these motions were possible because your skeleton has joints.

Any place where two or more bones meet is a **joint.** A model of a joint can be made from two cardboard tubes and some rubber bands. The tubes represent bones, and the rubber bands represent ligaments. A **ligament** is a tough band of tissue that holds bones together at joints. Many joints, such as your knee, are held together by more than one ligament.

Joints are classified as immovable or movable depending on how much movement can take place. An **immovable joint** allows little or no movement. The joints of the bones of your skull and pelvis are classified as immovable. A **movable joint** allows the body to make a wide range of movements. Shooting baskets or working the controls of a video game require movable joints. There are several types of movable joints: pivot, ball-and-socket, hinge, and gliding

In Your JOURNAL

You may have heard of an athlete who has had arthroscopic surgery on a knee. Find out about this procedure. **In your Journal,** describe how this surgery is different from other types of surgery.

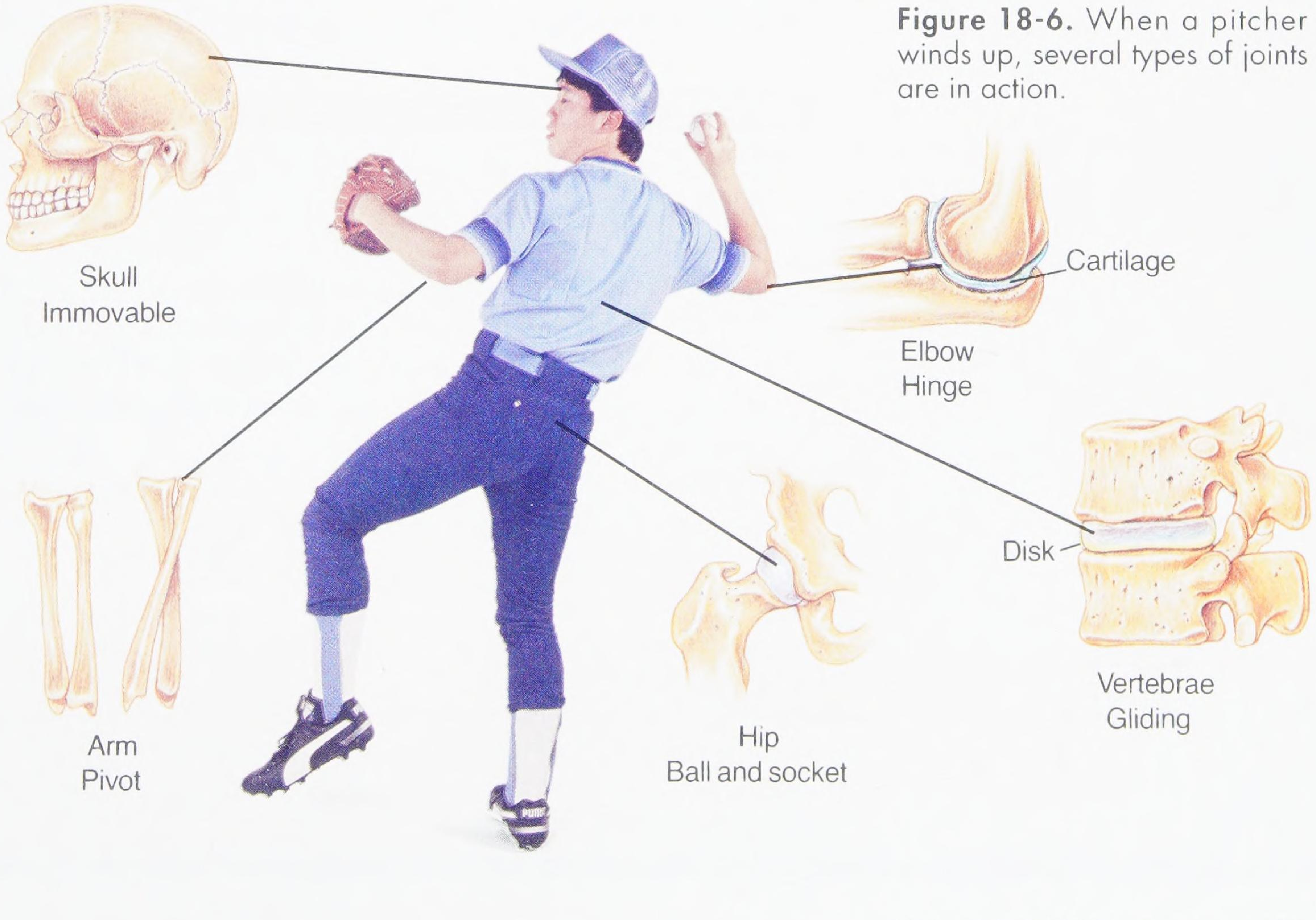


Figure 18-6. When a pitcher winds up, several types of joints are in action.

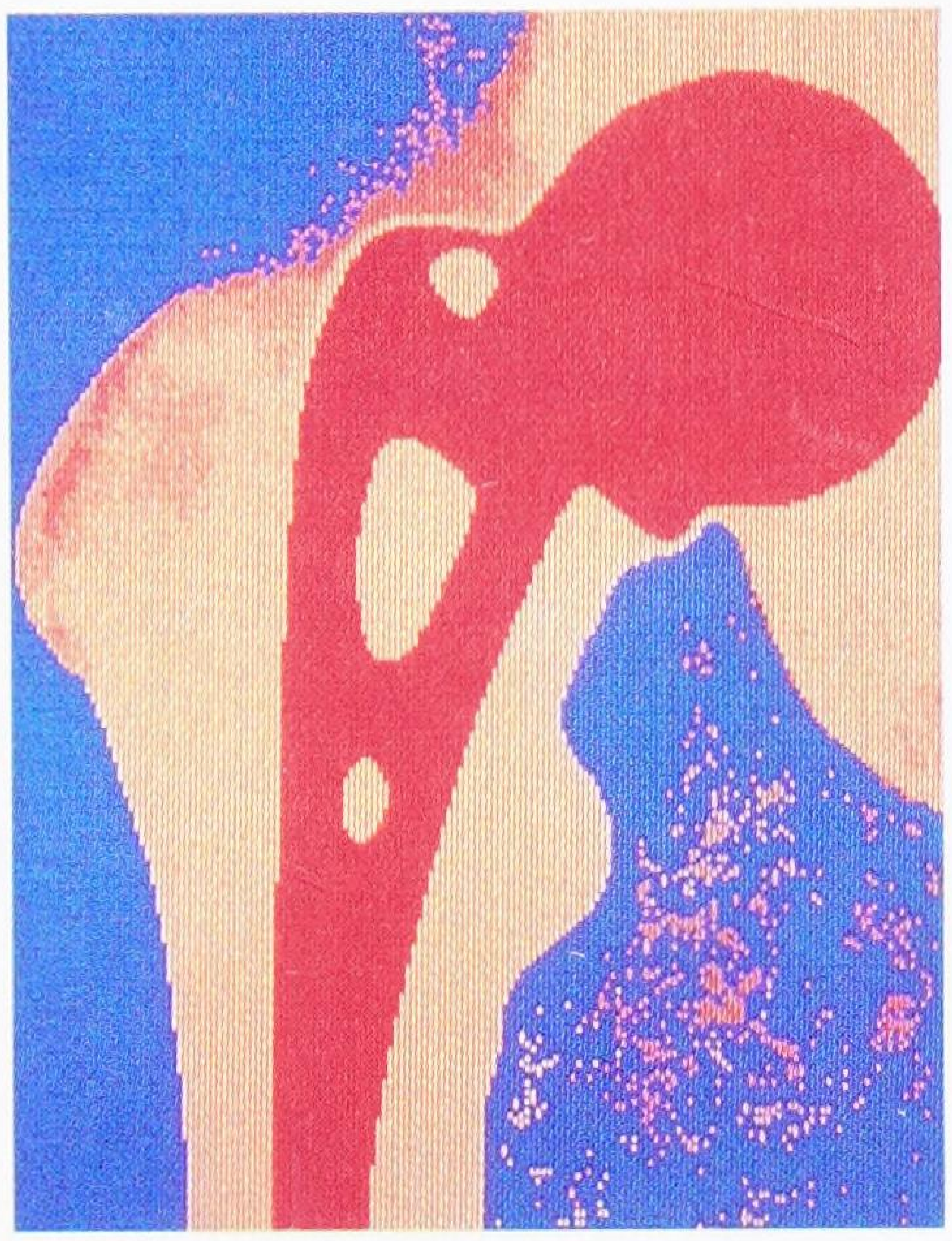


Figure 18-7. Certain joints, especially those in the hip, knee, and elbow, have been successfully replaced by artificial joints.

joints. In a pivot joint, one bone rotates in a ring of another bone. Turning your head is an example of a pivot movement. In a ball-and-socket joint, one bone has a rounded end that fits into a cuplike cavity on another bone. Knees and shoulders are examples.

A third type of joint is a hinge joint. This joint has a back and forth movement like hinges on a door. Elbows, knees, and fingers have hinge joints. A fourth type of joint is a gliding joint where one part of a bone glides over another bone. Gliding joints are found in your wrists and ankles and between vertebrae. Gliding joints are the most frequently used joints in your body. You can't write a word, pick up a sock, or take a step without using a gliding joint.

Cartilage helps make joint movements easier. It covers the ends of bones in movable joints. Your outer ear and the end of your nose are made of cartilage. Pads of cartilage called disks are also found between the vertebrae. Here, cartilage also acts as a cushion and prevents injury to your spinal cord.

Your skeleton is a living framework in the form of bones. Bones not only support the body but also supply it with minerals and blood cells. Joints are places between bones that enable the framework to be flexible and to be more than just a storehouse for minerals.

SECTION REVIEW

1. What are the five major functions of a skeleton?
2. What are two jobs of the periosteum?
3. Name and give an example of a movable joint.
4. What are the functions of cartilage?
5. **Apply:** The thick band of bone that forms around a healing broken bone is called a callus. In time it disappears. What is there in bone that enables this extra amount of bone to disappear?
6. **Connect to Chemistry:** Find out what materials many implants are made from.

Skill Builder

☑ Outlining

Outline the major functions of bone and give an example of each. If you need help, refer to Outlining in the **Skill Handbook** on page 681.

ACTIVITY 18-1

Observing Bones

Problem: *What are the parts of a long bone?*

Materials

- beef bone
- hand lens
- scalpel
- microscope slide
- microscope
- coverslip
- dropper
- water

Procedure

1. Make a table like the one shown.
2. Obtain a beef bone that has been cut in half along the length and width.
3. *Observe* the bone with a hand lens. *Identify* the periosteum, compact bone, spongy bone, and any marrow that is present.
4. Draw a *diagram* of the bone and label the parts you have been able to recognize. In the table, describe each part.
5. Use a scalpel to carefully remove a very small piece of red bone marrow. **CAUTION:** *Always use extreme care when using sharp instruments.*
6. Make a temporary wet mount slide of the marrow. Examine it under low power. Describe and draw what you see.

Data and Observations

FEATURES OF BONE

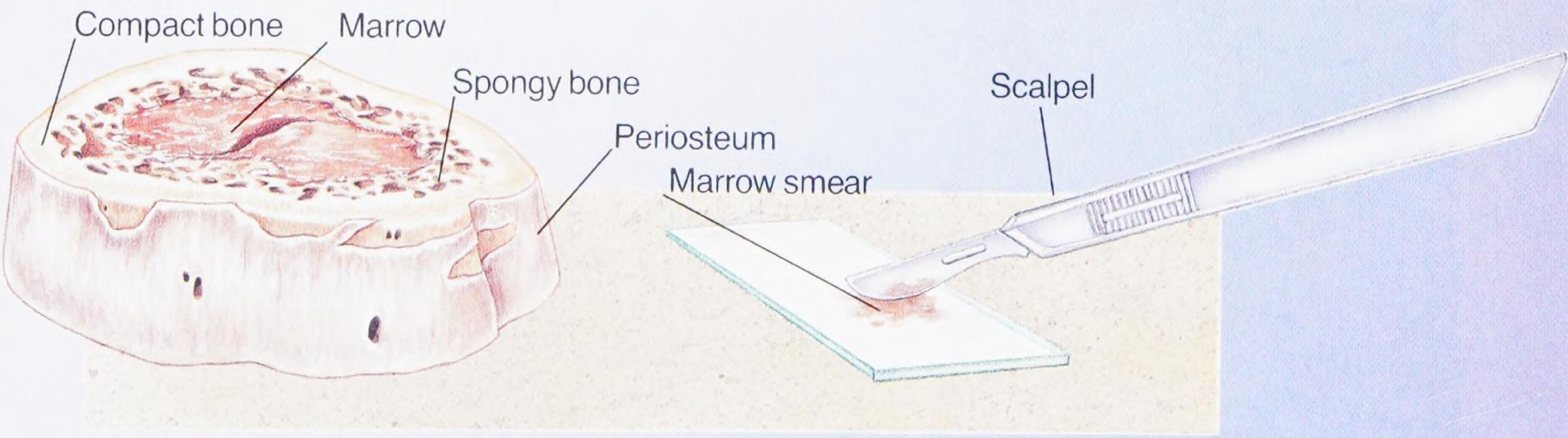
Part	Description
Periosteum	
Compact bone	
Spongy bone	
Marrow	

Analyze

1. What parts of the bone were you able to identify?
2. *Describe* the portions of the bone that contain marrow.
3. What differences did you observe in the overall shape of the bone?

Conclude and Apply

4. How might the function of the spongy bone area and the compact bone areas *relate* to the shape of the areas in which they are found?
5. From your observations, where would you *infer* that most calcium is stored in a long bone?



18-2 The Muscular System

New Science Words

muscle
voluntary muscles
involuntary muscles
skeletal muscles
tendons
smooth muscles
cardiac muscle

Objectives

- Describe the major function of muscles.
- Compare and contrast three types of muscles.
- Explain how muscle action results in movement of body parts.

The Muscular System

Bones and joints together are somewhat like simple machines, but on their own they have no power to move. Muscles are the motors that move body parts. There are more than 600 muscles in your body. This means that nearly 35 to 40 percent of your body mass is muscle tissue. No matter how still you might try to be, there is always movement taking place in your body. Every system in your body contains some type of muscle tissue as a part of that system. As a result, every part of your body is moved at some time during your life, if not every day. A **muscle** is an organ that contracts and gets shorter. As a result, body parts move. Energy is used, and work is done.

Voluntary muscles are muscles that you control. Your arm and leg muscles are voluntary. So are the muscles of your hands and face. You can choose to move them or not to move them. In contrast, **involuntary muscles** are muscles you can't consciously control. You don't have to decide to make these muscles work. They just go on working all day long, all your life. Blood gets pumped through blood vessels, and food is moved through your digestive system by the action of involuntary muscles. You can sleep at night without having to think about how to keep these muscles working.

Figure 18-8. Muscles of the Human Body

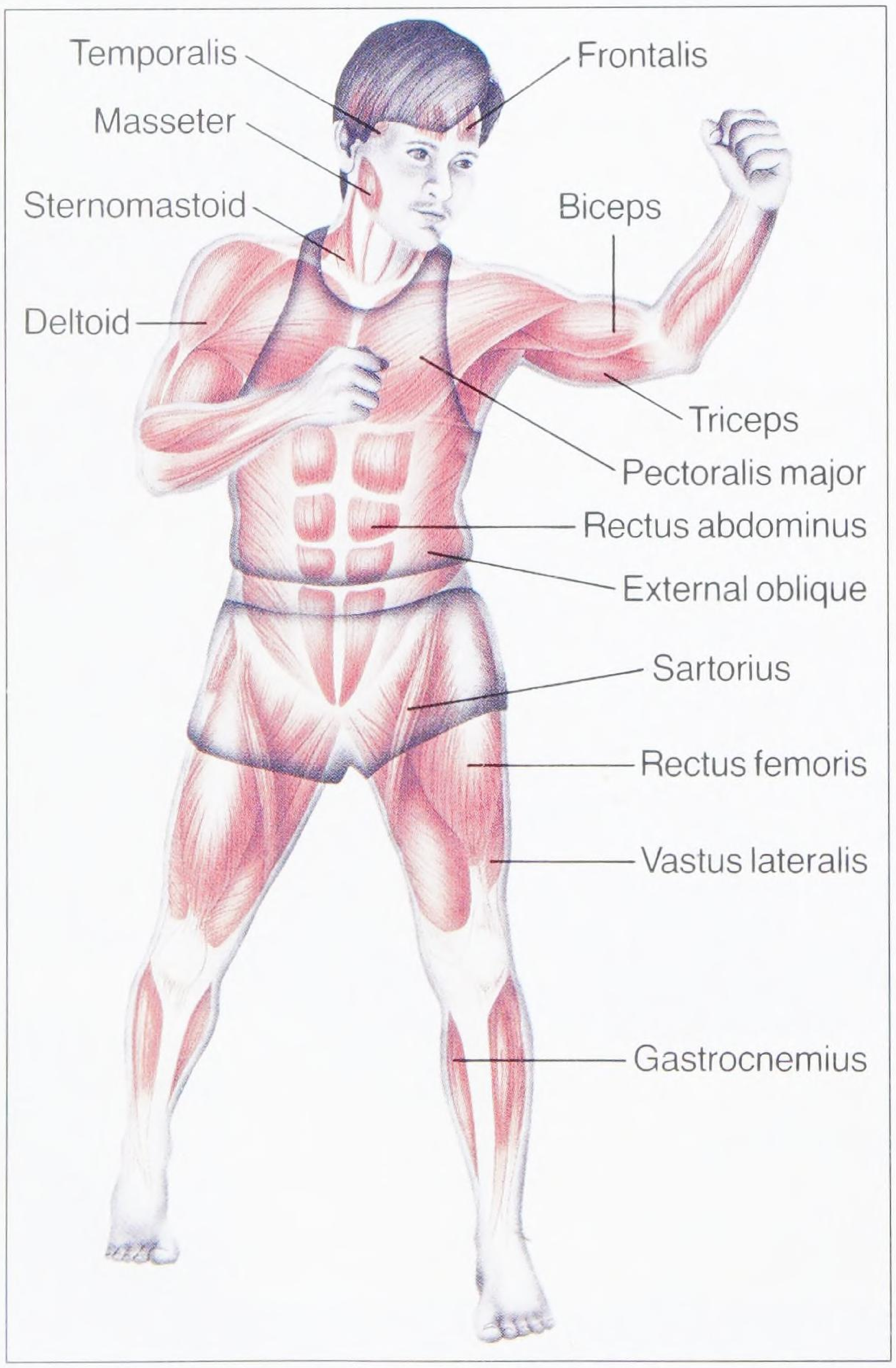
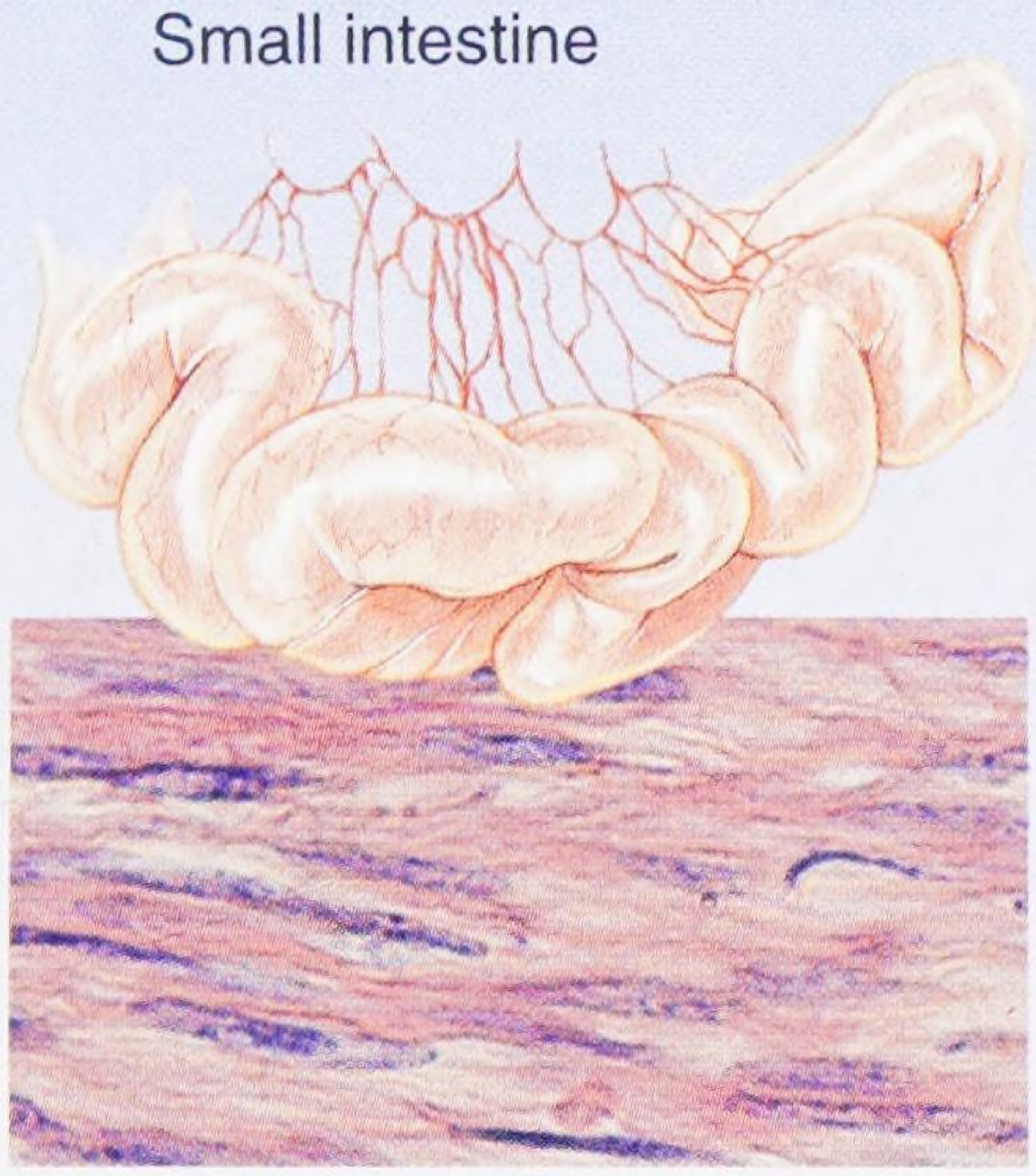
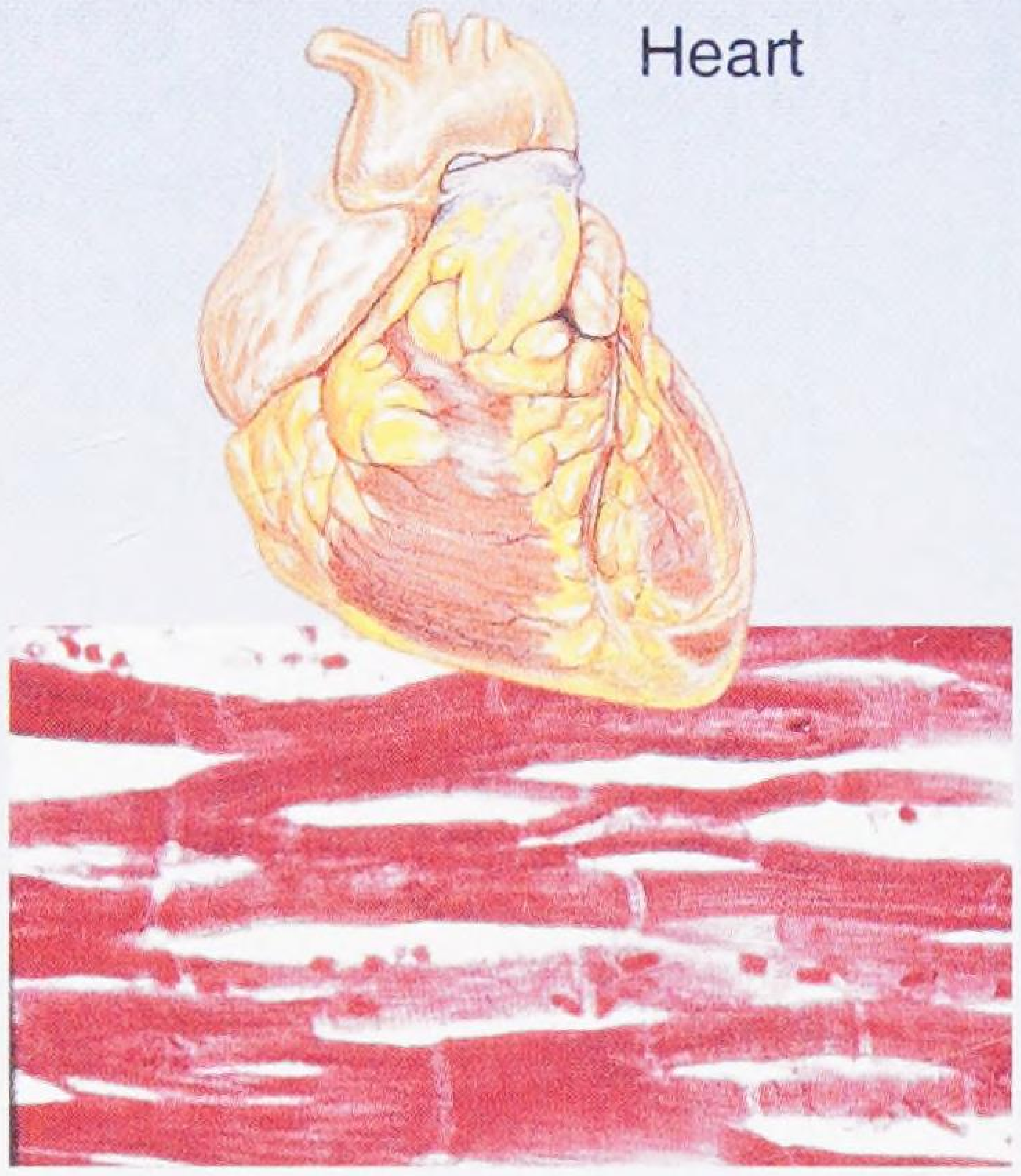
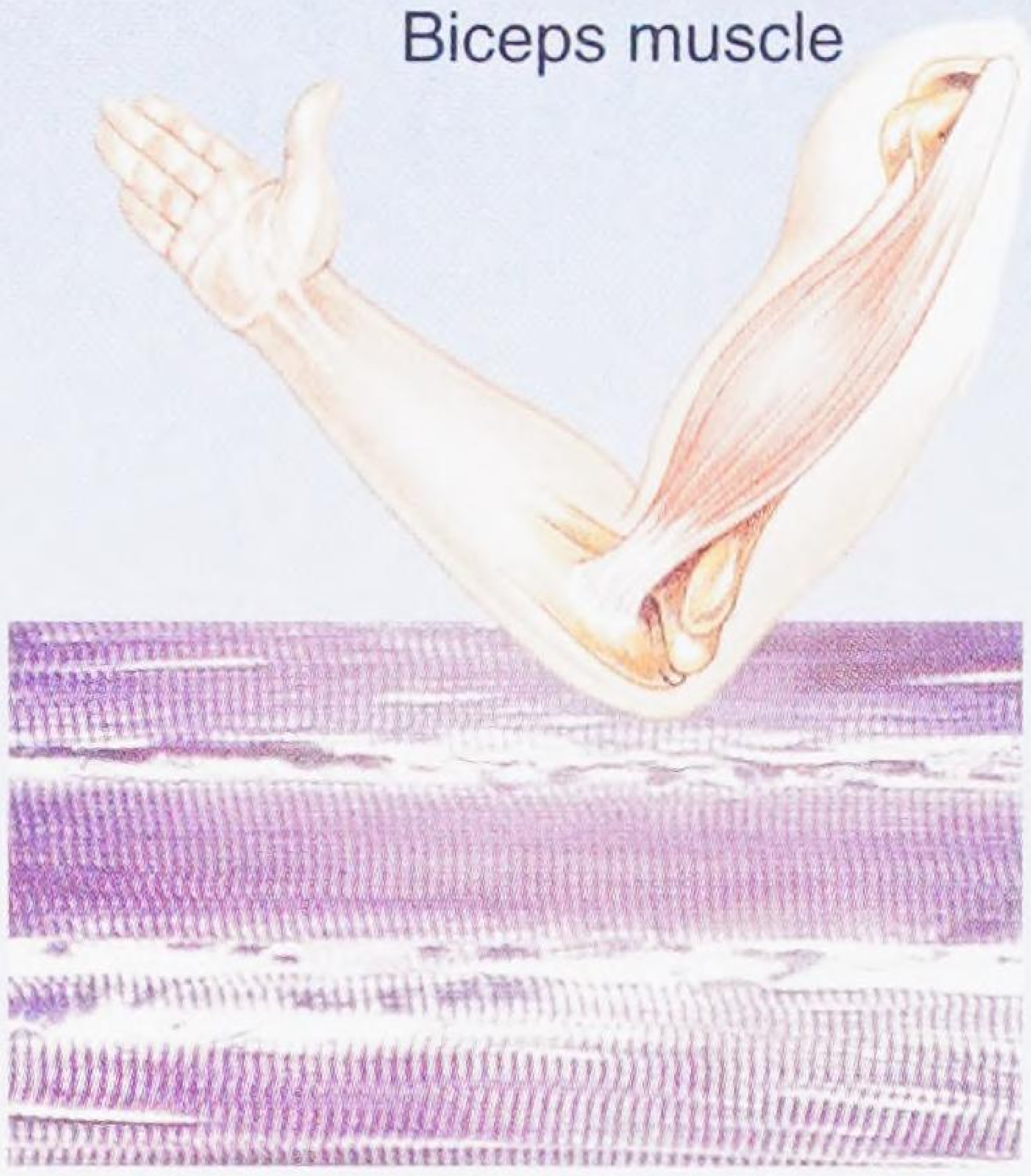

Temporalis
Frontalis
Masseter
Sternomastoid
Biceps
Deltoid
Triceps
Pectoralis major
Rectus abdominus
External oblique
Sartorius
Rectus femoris
Vastus lateralis
Gastrocnemius

Table 18-1

TYPES OF MUSCLE

Smooth muscle	Cardiac muscle	Skeletal muscle
Control: Involuntary	Control: Involuntary	Control: Voluntary
Appearance: Smooth	Appearance: Striped	Appearance: Striped
Location: Internal organs	Location: Only the heart	Location: Attached to bone
		

Three Types of Muscle Tissue

There are three types of muscle tissue in your body: skeletal, smooth, and cardiac. Skeletal muscles are the most numerous muscles in the body. Under a microscope, skeletal muscle cells look striped, or striated. **Skeletal muscles** are attached to bones by tendons. **Tendons** are thick bands that pull on the bone as the muscle contracts. Skeletal muscles are voluntary muscles. You can control their use. You choose when to walk or not to walk. Skeletal muscles tend to contract quickly and tire easily.

Smooth muscles are involuntary. The walls of the stomach, intestine, uterus, bladder, penis, and blood vessels are some of the places where one or more layers of smooth muscle are found. Smooth muscles contract and relax slowly. They have no striations.

The third type of muscle, **cardiac muscle,** is found only in the heart. Cardiac muscle is also involuntary. As you can see from Table 18-1, cardiac muscle has striations like skeletal muscle. However, cardiac muscle is like smooth muscle in that it is involuntary. Cardiac muscle contracts about 70 times per minute every day of your life. You know each contraction as a heartbeat, but it isn't something you can control.

Science and MATH

Because of regular exercise during the track season, Hope was able to reduce her at-rest pulse rate from 76 beats per minute to 66. *Estimate* how many beats Hope is saving her heart muscle per day.

Muscles at Work

Skeletal muscle movements are the result of pairs of muscles working together. When one muscle of a pair contracts, the other muscle relaxes, or returns to its original length. Sit up straight in a chair with your feet on the floor as in Figure 18-9a. Slowly bring your right leg up so that your leg is straight out. Now slowly bring the leg down so that your right foot is on the floor again. When you straighten your leg at the knee, one set of muscles in the upper part of your leg contracts. This causes the bones of your lower leg to be pulled straight up. Muscles always pull; they never push. When your leg moves down, muscles on the back of your upper leg contract to pull the leg downward.

When you straightened your leg, your muscles used energy. Muscles use chemical energy in the form of glucose. As the bonds in glucose break, chemical energy changes to mechanical energy and the muscle contracts. When the supply of glucose in a muscle gets used up, it becomes tired and needs to rest. Muscles also produce thermal energy when they contract. The heat produced by muscle contraction helps to keep your body temperature constant.

Over a period of time, muscles can become larger or smaller, depending on how much work they do. Skeletal muscles that do a lot of work, such as those in your writing hand or in the arms of a brick layer, become large and strong. In contrast, if you just sit and watch TV all day, your muscles will become soft and flabby, and will lack strength. Muscles that aren't exercised become smaller in size.

MINI-Lab

How do muscle pairs work?

Work with a partner. Stretch your arm out straight. Then bring your hand to your shoulder, then down again. Using a muscle chart, have your partner *determine* which skeletal muscles in your upper arm enable you to perform this action. **In your Journal,** draw and label the changes that take place in the arm.

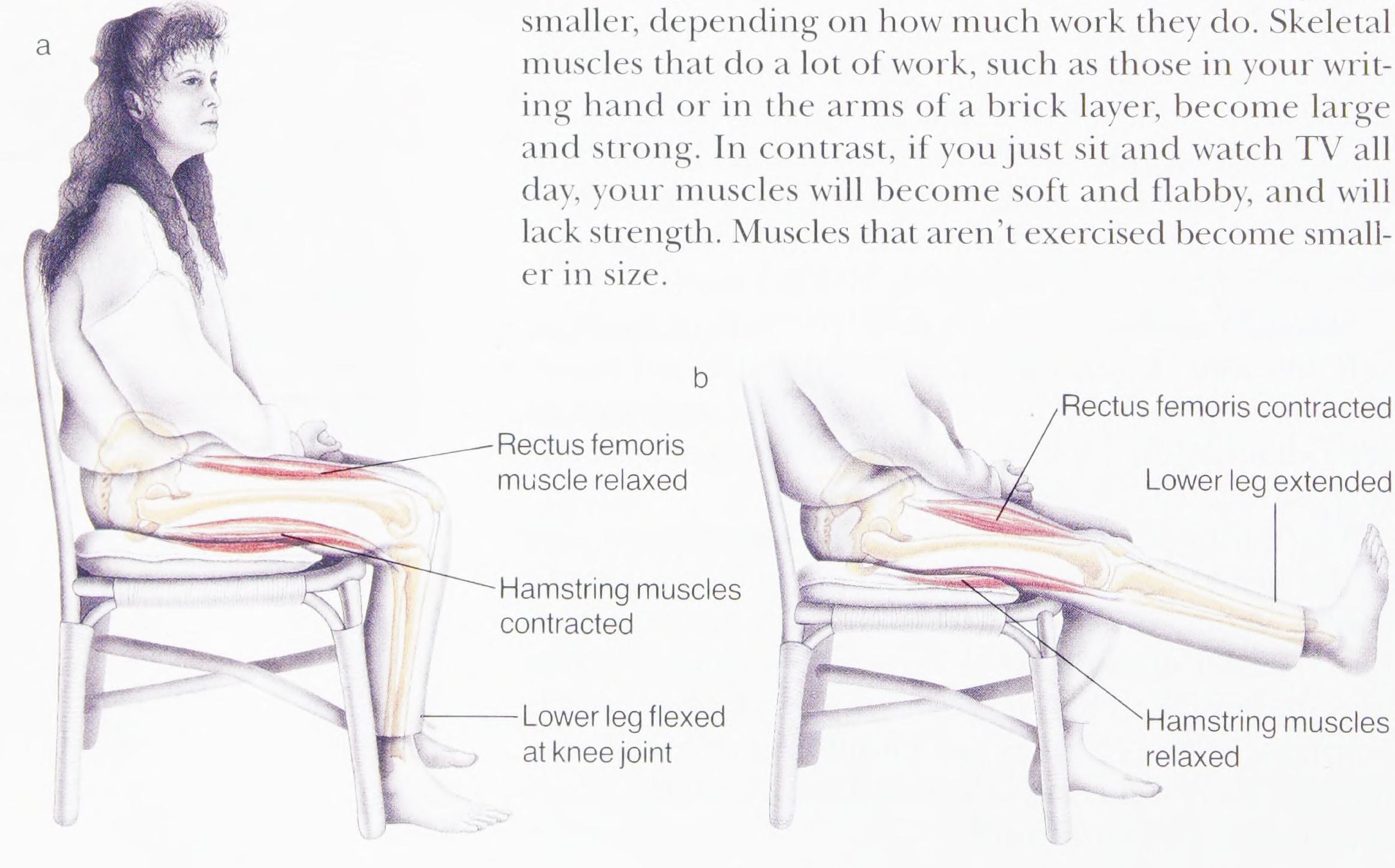

a
Rectus femoris muscle relaxed
Hamstring muscles contracted
Lower leg flexed at knee joint
b
Rectus femoris contracted
Lower leg extended
Hamstring muscles relaxed

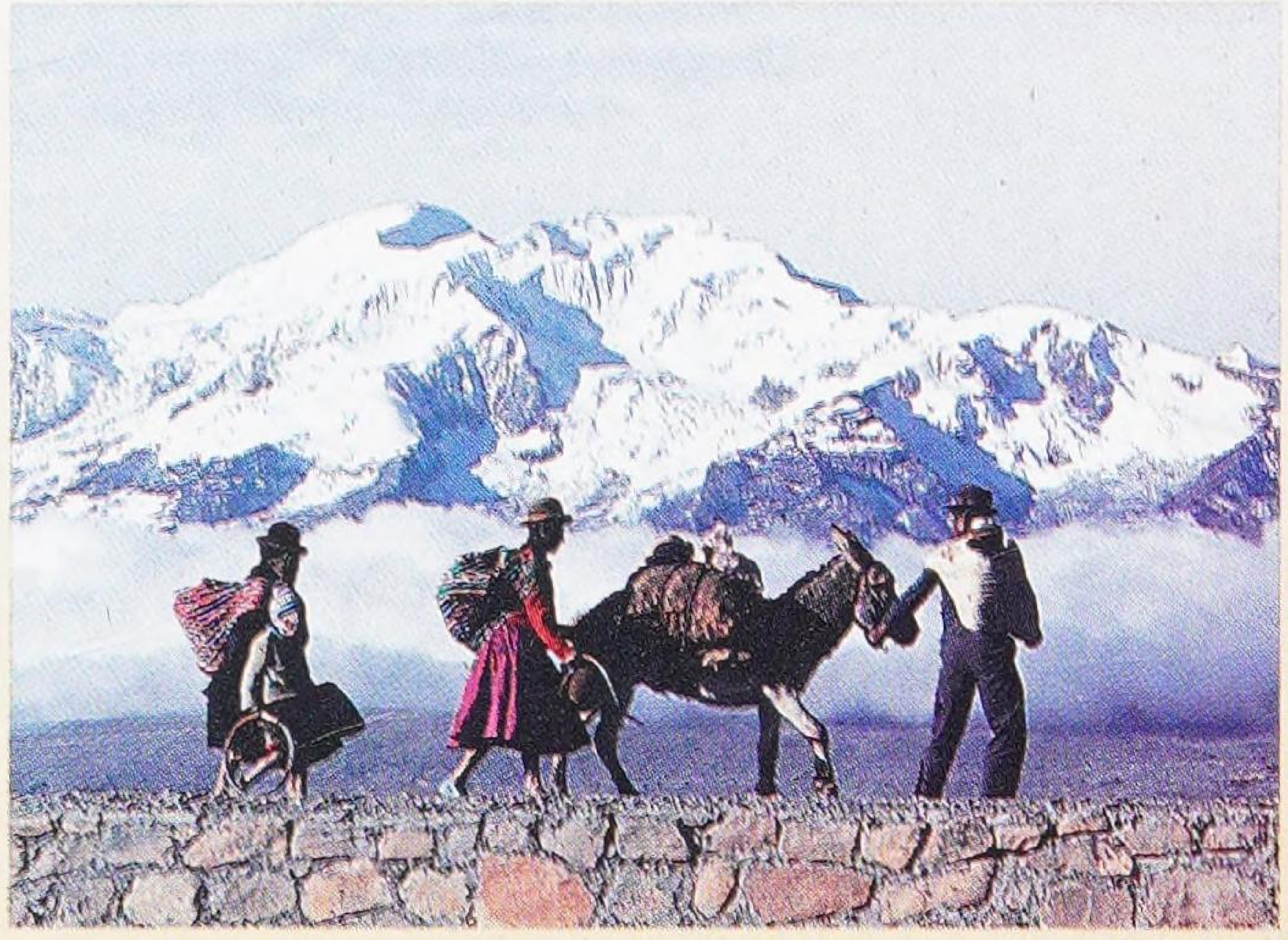
Figure 18-9. Skeletal muscles work in pairs. When one muscle in a pair contracts, the other is relaxed.

PROBLEM SOLVING

High Altitude Bones

People living at high altitudes have a number of environmental stresses different from those faced by people at lower altitudes. Oxygen pressure is low and soil is poor. There are strong winds and high solar radiation. Many people live at high altitudes, but the two areas studied the most are the Andes in Peru and the Himalayas in Tibet. Individuals in both of these places have bones that grow more slowly than the bones of people living at sea level. Because their skeletal growth is slower, people living at high altitudes tend to be relatively short. They also reach maturity as much as two to four years later than people living at sea level.

Think Critically: Which two stresses mentioned above contribute to slowed skeletal growth?



Could you lift and lower your leg all day? What would it feel like after one minute? After five minutes? Your leg would probably feel tired and achy after five minutes of flexing, don't you think? Large and small muscles need to rest from time to time to be resupplied with glucose.

SECTION REVIEW

1. What is the function of the muscular system?
2. Compare and contrast the three types of muscle.
3. What attaches a muscle to a bone?
4. **Apply:** What happens to your muscles when you bend your arm at the elbow?
5. **Connect to Physics:** What three forms of energy are involved in a muscle contraction?

Connect to... Chemistry

Muscle cells contain a protein called myoglobin that is similar to hemoglobin in red blood cells. Hemoglobin is a red pigment that carries oxygen. From this information, what can you *infer* about myoglobin?

Skill Builder

Sequencing

Sequence the activities that take place when you bend your leg at the knee. If you need help, refer to Sequencing in the **Skill Handbook** on page 680.

SCIENCE & SOCIETY

18-3 Drugs for Fitness?

New Science Words

anabolic steroids

Objectives

- List side effects of anabolic steroid use.
- Discuss the use of anabolic steroids among athletes.

Do Steroids Give a "Winning Edge"?

Have you stood in front of the mirror flexing your muscles, wishing you looked like the bodybuilders you've seen on TV or in magazines? In our society, a well-built body is often admired. Athletes from junior high school students to the top professionals feel the desire to be bigger, better, or faster. They spend hours each week training and building their muscles. But some athletes feel that they aren't getting big enough fast enough. Some even turn to misuse of drugs called anabolic steroids.

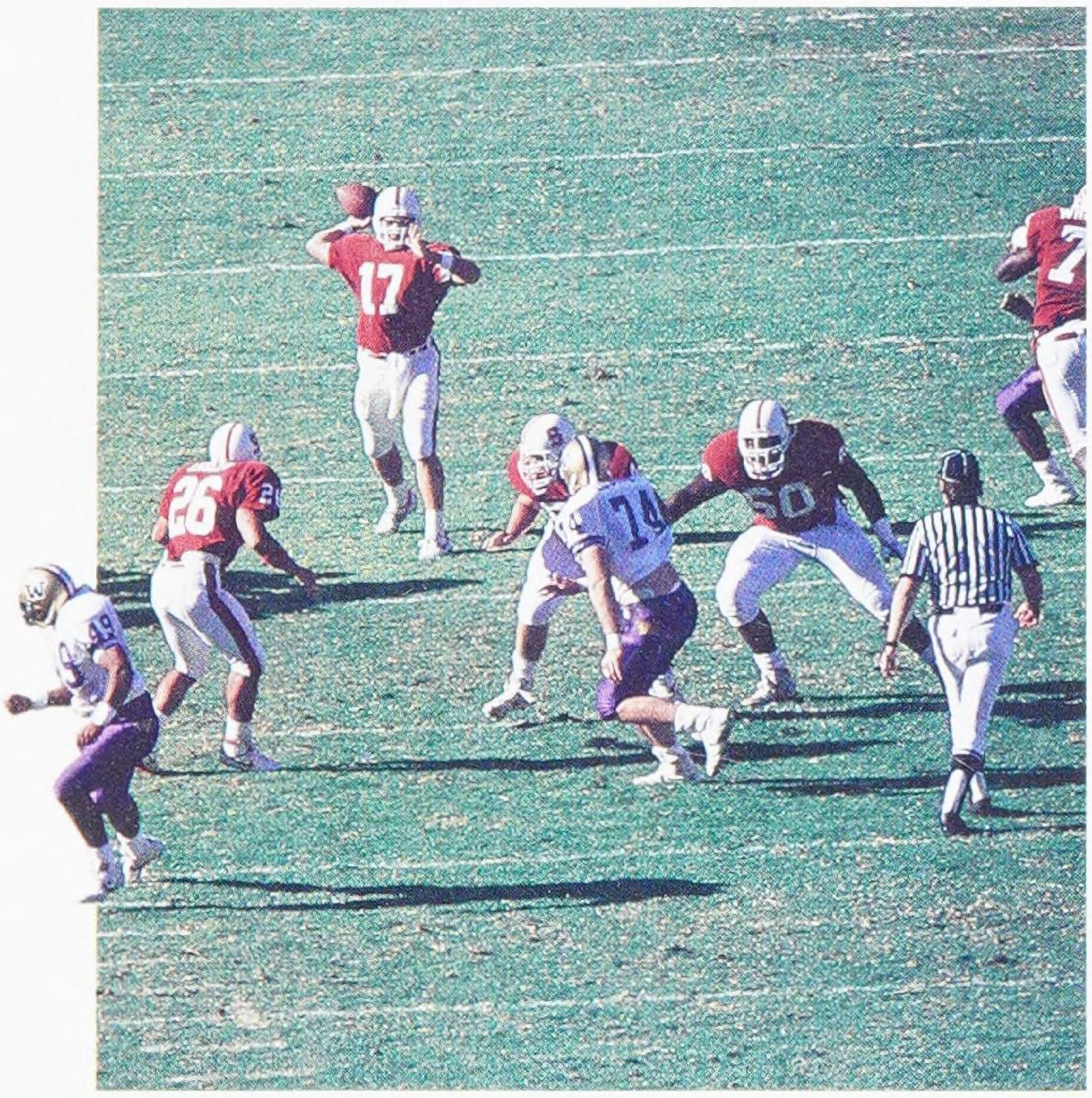


Figure 18-10. Abuse of anabolic steroids among high school athletes causes health problems.

Anabolic steroids are drugs that contain a variation of the hormone testosterone. Testosterone occurs naturally in both men and women, but it reaches much higher levels in males. It produces male characteristics such as a deep voice. Anabolic steroids were originally developed in the 1930s to help sick people build muscle tissue.

Many athletes feel that if normal amounts of testosterone are good for muscle building, then increased amounts are even better. But is this true?

Athletes who use anabolic steroids may endanger their health. When women use steroids, they may grow excessive facial hair, their voices may deepen, and their breasts may shrink. In males, steroid use may cause testicles to shrink and small lumps of breast tissue to develop. Both males and females may develop hypertension and experience emotional swings. When taken in abusive amounts, some athletes have become extremely aggressive, retain excess water, and show excessive acne. When adolescents use steroids, their growth can be stunted, and that growth can't be made up in later life.

Is steroid use worth it? Does it give an athlete the "winning edge"?

In 1988, Canadian athlete Ben Johnson won a gold medal at the Olympic games in Seoul, Korea. He ran the 100-meter race in 9.79 seconds, a world record. Three days later Ben Johnson's gold medal and world record were taken from him. Olympic officials had found anabolic steroids in his urine sample. Like most major amateur sporting events, the Olympics ban the use of steroids and other drugs. Johnson has since said that he had used steroids for about seven years.

Some college and professional athletes are known to use anabolic steroids. Some feel strongly that when taken in prescribed doses, these drugs are safe, promote healing of damaged tissues, and enhance athletic ability. The greater concern comes from the use of these drugs by developing adolescents who may think more is better and misuse the drugs.

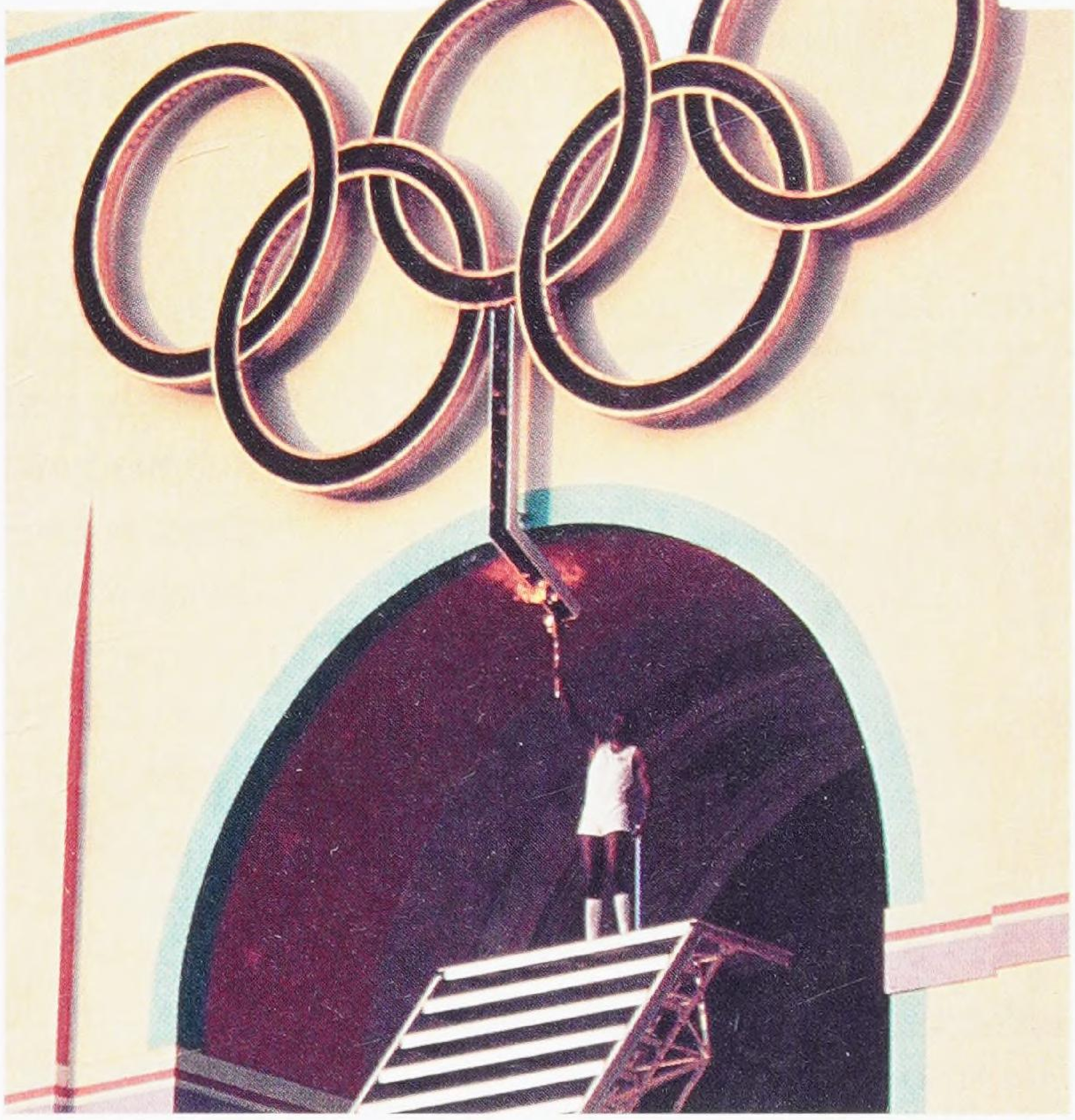


Figure 18-11. In 1984, the International Olympic Committee banned the use of anabolic steroids to maintain fairness in the events.

An additional problem becomes clear. If athletes use drugs such as anabolic steroids, is real athletic ability being demonstrated? How fair is the high school track meet if some athletes use the drugs? And what price do students pay? One researcher has warned that the drugs are too powerful not to have some damaging effects if used over a long period.

SECTION REVIEW

1. Why were anabolic steroids originally developed?
2. What are some of the side effects of anabolic steroid use?

SCIENCE & SOCIETY

You Decide!

Tests have been developed to detect the presence of anabolic steroids in blood and urine. Should professional and college athletes be allowed to use these drugs? What about younger athletes? Steroid abuse has been found in junior high and high school students. Should school athletes be allowed to use these drugs, even if prescribed?

18-4 Skin

New Science Words

epidermis
melanin
dermis

Objectives

- Compare and contrast the epidermis and dermis of the skin.
- List the functions of the skin.
- Discuss how skin protects the body from disease and how it heals itself.

Did You Know?

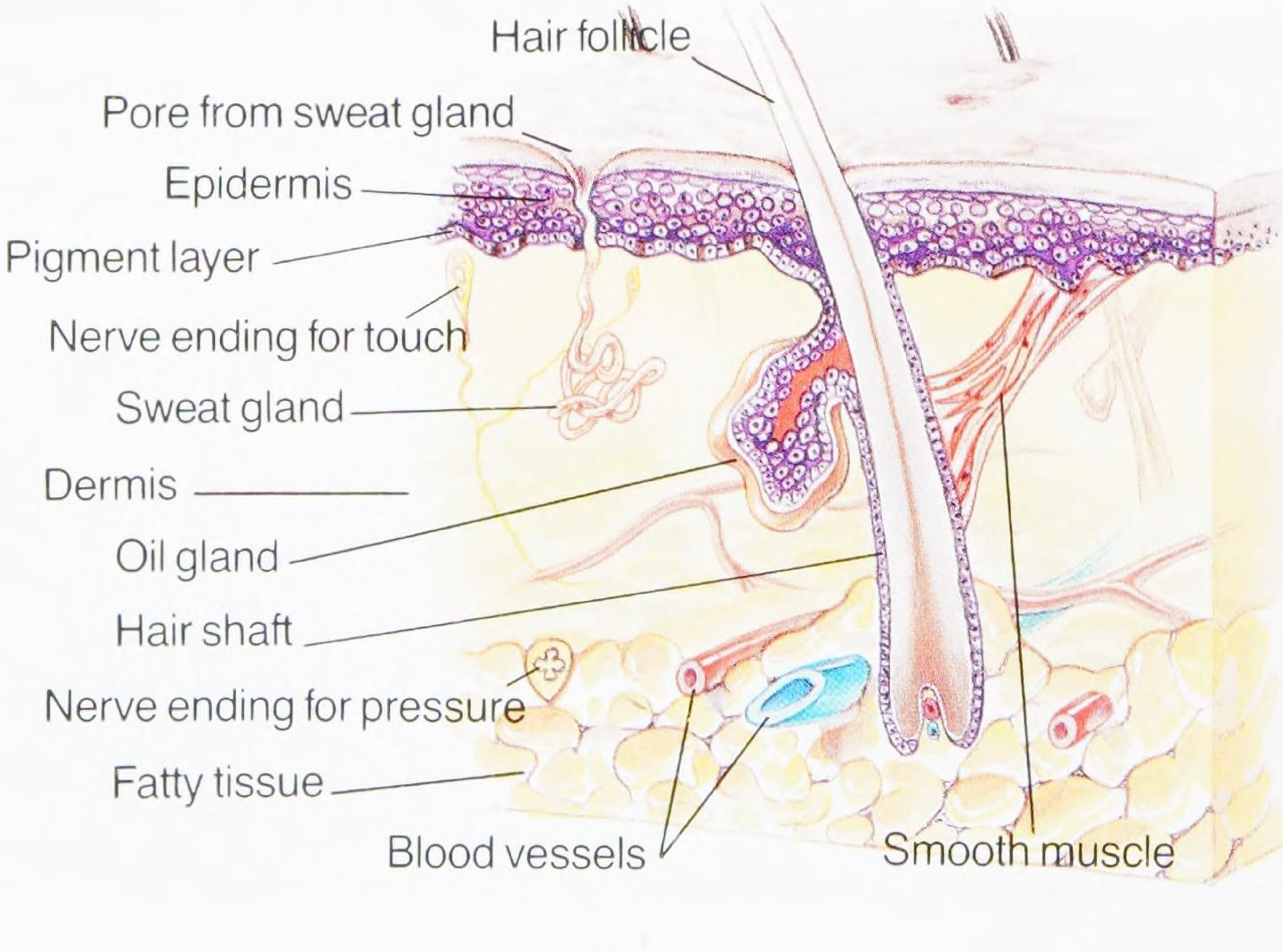
Goose bumps result when small smooth muscles at the base of each hair in your skin contract. Each hair stands on end as the muscle pulls on the hair.

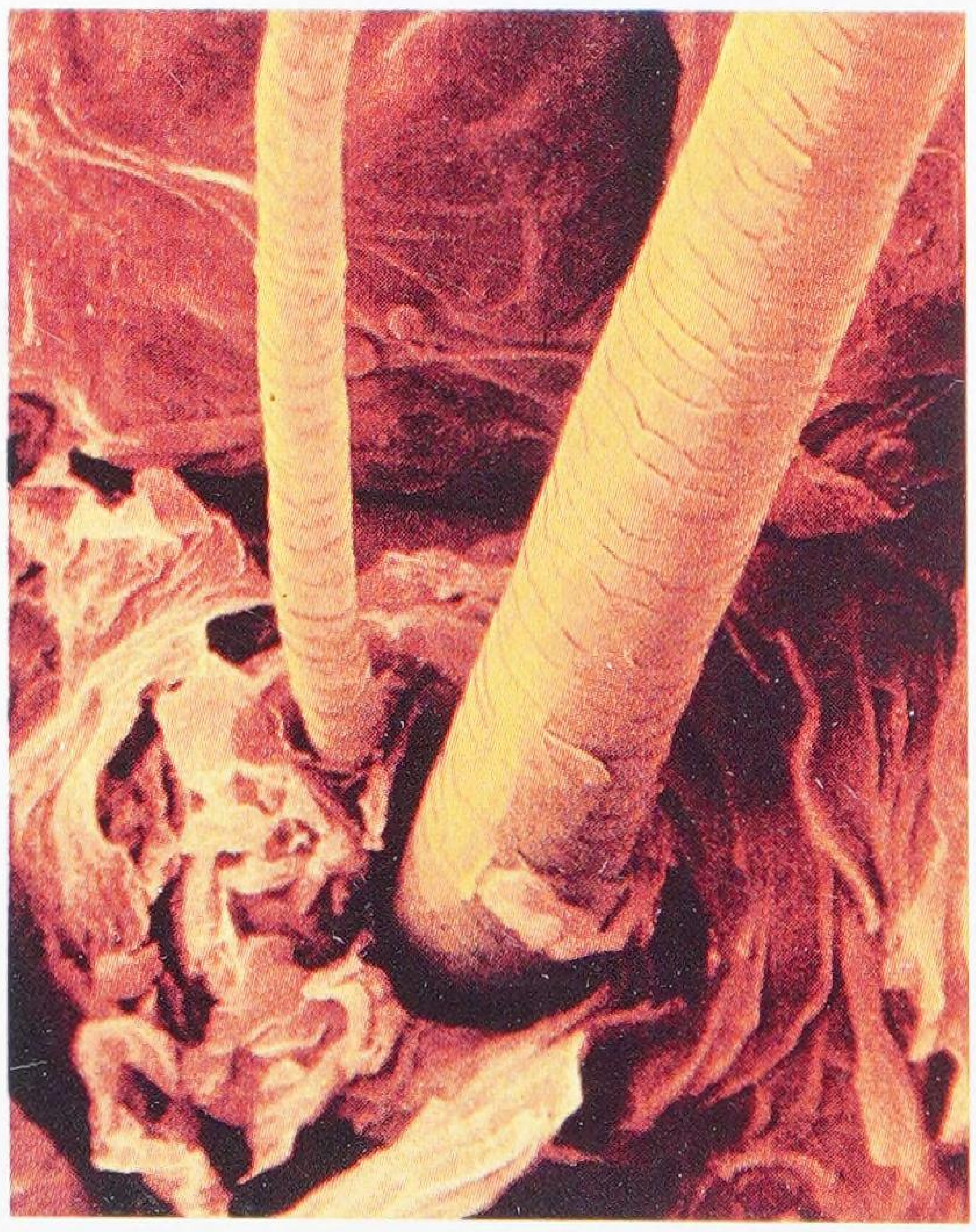
The Body's Largest Organ

Your skin, hair, nails, and millions of sweat and oil glands are part of your body's largest system, the integumentary (ihn teg yuh MENT uh ree) system.

Skin is the largest organ of your body. It is the one organ you are most familiar with, yet you may know less about your skin than about your muscles. Much of the information you receive about your environment comes through your skin. Only a few millimeters thick in most places, skin is made up of two layers of tissue, the epidermis and the dermis. The **epidermis** is the surface layer of your skin. The cells on the top of the epidermis are dead. Thousands of these cells rub off every time you take a shower, shake hands, blow your nose, or scratch your elbow. New cells are constantly produced at the bot-

Figure 18-12. Skin is made up of two layers, the epidermis and the dermis. The dermis contains blood vessels, glands, and nerves.


Hair follicle
Pore from sweat gland
Epidermis
Pigment layer
Nerve ending for touch
Sweat gland
Dermis
Oil gland
Hair shaft
Nerve ending for pressure
Fatty tissue
Blood vessels
Smooth muscle



tom of the epidermis to replace the ones that are rubbed off. Cells in the epidermis produce the chemical melanin (MEL uh nun). **Melanin** is a pigment that gives your skin color. The more melanin, the darker the color of the skin. Melanin increases when your skin is exposed to the ultraviolet rays of the sun. If someone has very few melanin-producing cells, very little color gets deposited. These people have less protection from the sun. They burn more easily and may develop skin cancer more easily.

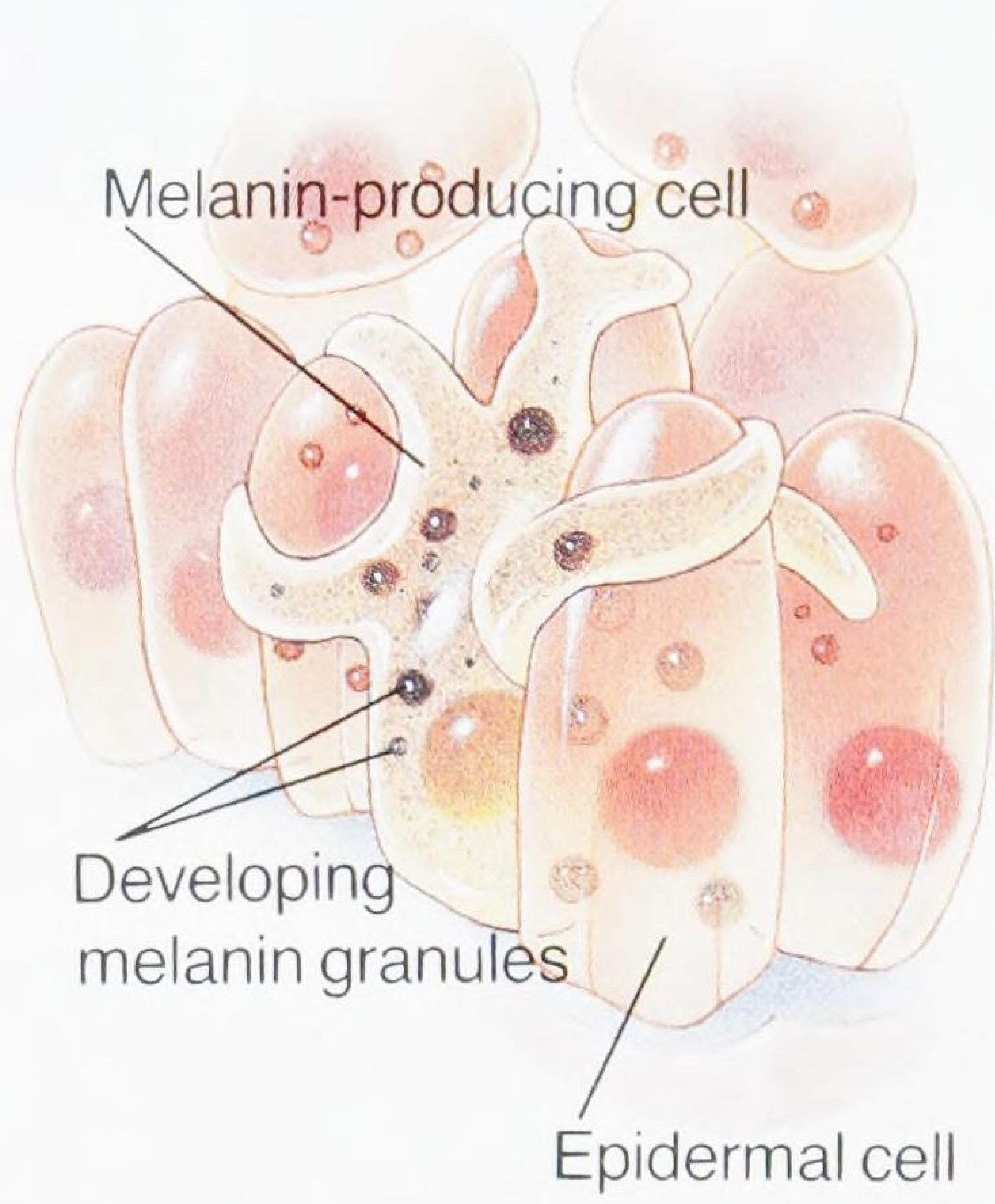


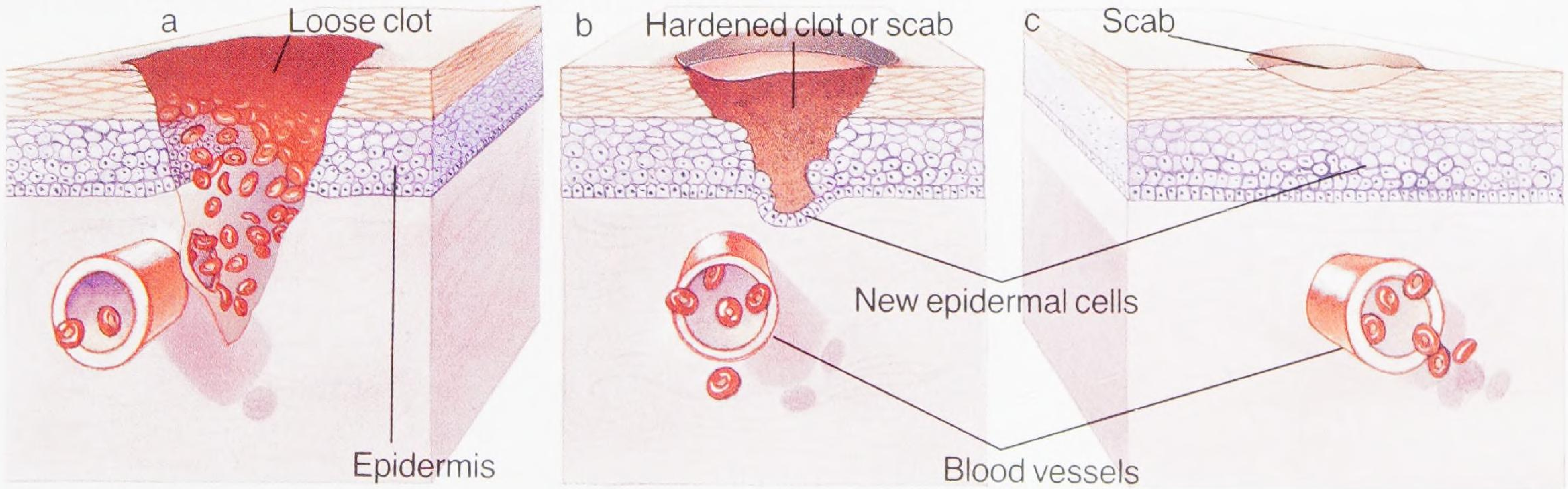
Figure 18-13. Pigment cells release melanin, which moves into other cells in the skin.

The **dermis** is the layer of tissue under the epidermis. This layer is thicker than the epidermis and contains many blood vessels, nerves, and oil and sweat glands. Notice in Figure 18-12 that under the dermis there are fat cells. This fatty tissue insulates the body. When a person gains too much weight, this is also where much of the extra fat is deposited.

The epidermis may be very thin, but injury to large areas of the skin can cause death. If the epidermis is burned away in a third degree burn, there are no cells left that can divide to replace this lost layer. As a result, nerve endings and blood vessels in the dermis are exposed. Water is lost rapidly from the dermis and muscle tissues. Body tissues are exposed to bacteria and to potential infection, shock, and death.

If injury to the epidermis is slight, a scab forms as in Figure 18-14. In scab formation, cells of the deepest layer of the epidermis can reproduce to cover the injured dermis. Later, the scab falls off on its own.

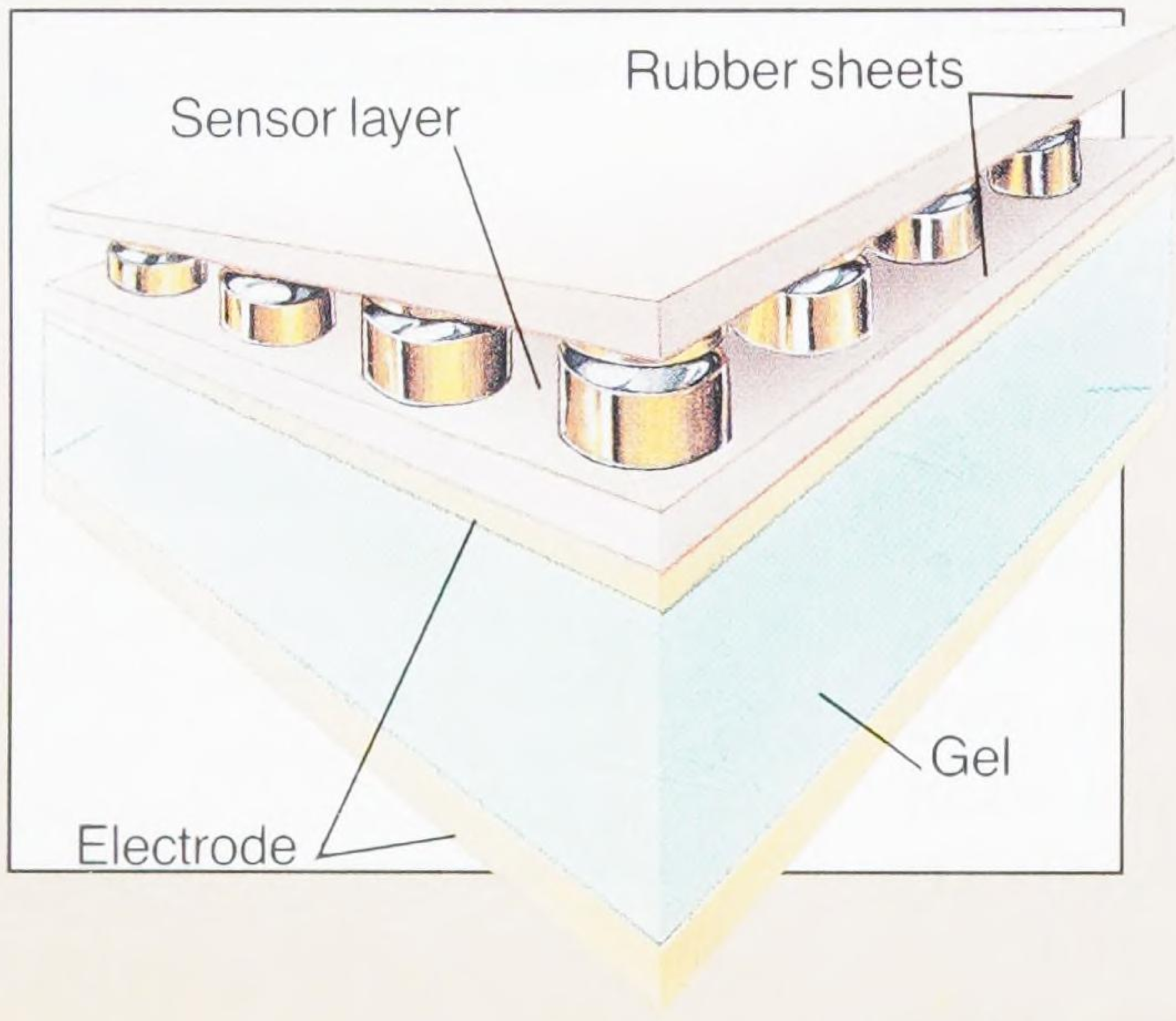
Figure 18-14. Within minutes of an injury, a loose blood clot forms (a). In a few days, new cells from the epidermis grow under the hardening clot (b). In a week, the hardened scab is ready to be pushed off (c).



TECHNOLOGY

Robot Skin

Industrial robots are programmed to use a specific force to pick up an object. So long as they are built to handle a specific type of object, this works well. But, what if a robot had sense organs? Then it could adjust itself to doing different tasks.



Scientists are developing an artificial skin for robots that can sense the difference between a rock and a tomato and handle each correctly. The artificial skin is modeled after human skin. The outer layer is made of electrode sheets with gel between them. This layer reads the amount of pressure placed on an object. The inner layer consists of a layer of sensors between two rubber sheets. These sensors can detect very fine textures and friction.

Right now, scientists are looking for a way to make the artificial skin without making it too thick.

Think Critically: Explain why artificial skin should not be too thick.

Skin at Work

Your skin has five major functions. First, it forms a protective covering over the body. As a covering, it prevents injury and disease. A large bacterial population that lives on the surface works to destroy invading pathogens. Skin prevents excess water loss from body tissues.

Second, skin has an important homeostasis function because it helps regulate body temperature. Humans, unlike most fur-bearing animals, have very little hair to help them regulate body temperature. Hair is an adaptation that usually helps control body temperature. Instead, sweating cools the body. Blood vessels in the skin can help hold or release heat.

There are about three million sweat glands in the dermis. These glands help rid the body of wastes. They are also part of the body's method of keeping body temperature constant. When the body gets hot, blood vessels expand or dilate. Pores leading to sweat glands in the

Connect to...
Earth Science

Find out about the effects of ultraviolet radiation on skin. Why do mountain climbers risk becoming severely sunburned even in freezing temperatures?

Figure 18-15. The epidermis of many mammals produces much more hair than in humans.

skin open. Perspiration, or sweat, moves out onto the skin. The body then cools as sweat evaporates. This system balances heat produced by muscle contractions.

A third function of the skin is to excrete wastes. Sweat glands release water, sodium chloride, and a protein product called urea. Fourth, skin serves as a sensory organ. Nerve endings in skin pick up information about temperature, touch, and pressure. The fifth function is the formation of vitamin D. Small amounts of this vitamin are produced in the epidermis in the presence of sunlight. Vitamin D is needed to absorb calcium.

MINI-Lab

Is there water in sweat?

Note the color of a piece of cobalt chloride paper; record. With a medicine dropper, add a drop of water. *Observe* and *record* the color now. Do vigorous jumping jacks for three minutes, being sure to clap your hands. Then hold the cobalt chloride paper in your hand. What color is it now? What can you *conclude* about the distribution of sweat glands on your hands? Is there an advantage to having sweat glands on the palms of your hands?

SECTION REVIEW

1. Compare and contrast the epidermis and dermis.
2. List the five functions of skin.
3. How does skin help prevent disease in the body?
4. Explain how a scab forms.
5. **Apply:** Why is a person who has been severely burned in danger of death from loss of water?
6. **Connect to Physics:** Find out what insulation is, and why hair and fur are insulators.

Skill Builder

Concept Mapping

Make an events chain concept map to show how skin helps keep body temperature constant. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

ACTIVITY 18-2

Observing Muscle

Problem: *What do different types of muscle look like?*

Materials

- prepared slides of smooth, skeletal, and cardiac muscles
- microscope
- cooked turkey leg
- dissecting pan or cutting board
- dissecting probes (2)
- hand lens

Procedure

Part A

1. Using the microscope, first on low power, and then on high power, *observe* three different types of muscle on prepared slides.
2. On a sheet of paper, draw and label each type of muscle that you observe.

Part B

3. Muscle tissue is made up of groups of cells held together in fibers, usually by a transparent covering called connective tissue. Obtain a piece of cooked turkey leg from your teacher. On the cutting board, use the two probes to tease the muscle fibers apart.
4. *Use a hand lens* to examine the muscle fibers and any connective tissue you see from the turkey leg.
5. *Draw* and *measure* five turkey leg fibers and describe the shape of these muscle fibers.

Data and Observations

<table>
<tr><th>Skeletal</th><th colspan="5">Cardiac</th><th colspan="5">Smooth</th></tr>
<tr><td></td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td>Length of fibers</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="11"></td></tr>
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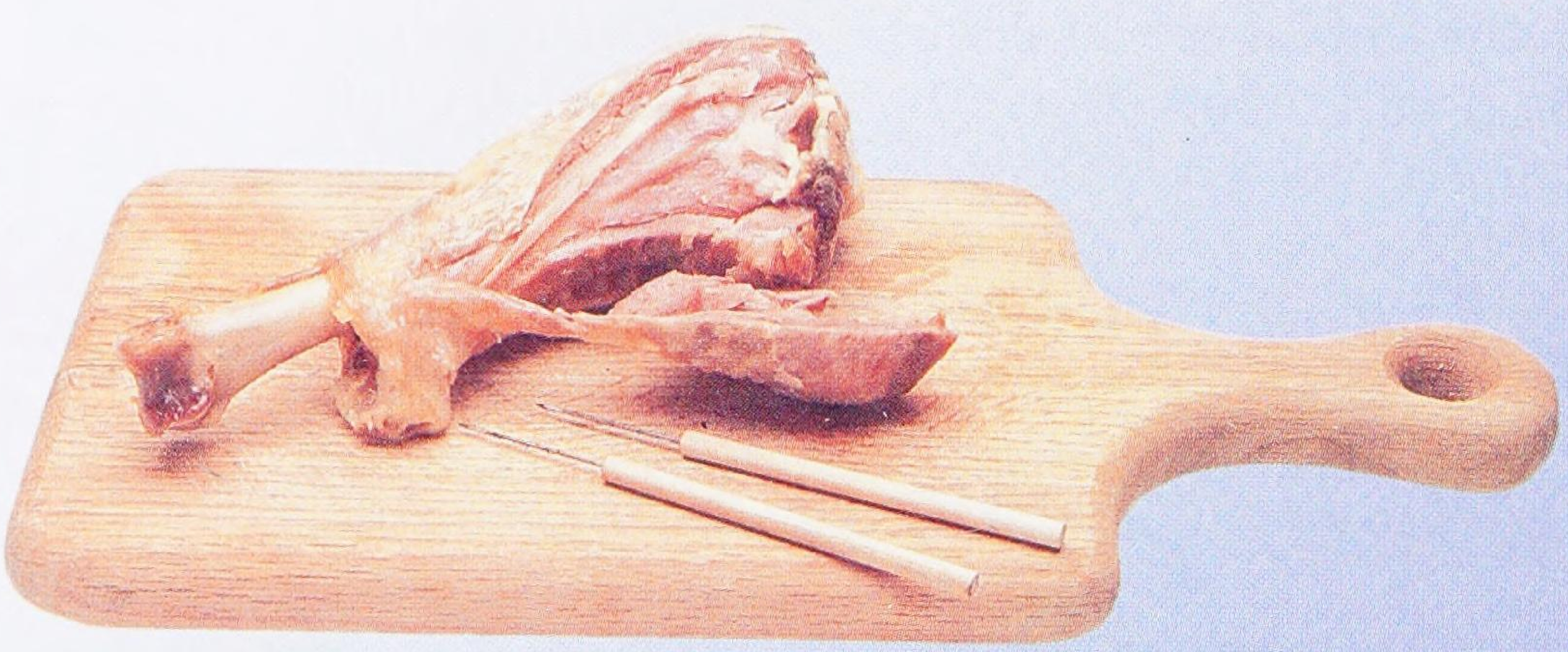
Analyze

1. Which muscles on the slides have stripes, or striations?
2. How long are the muscle fibers in the turkey leg?
3. What type of muscles are there in a turkey leg?
4. How are muscle fibers arranged in the prepared slides and in the turkey leg?

Conclude and Apply

5. *Predict* how the shape of a muscle fiber *relates* to its function.
6. Can you *conclude* that striations have anything to do with whether a muscle is voluntary or involuntary? Explain.



CHAPTER REVIEW

SUMMARY

18-1: The Skeletal System

1. Bones are living structures that protect, support, make blood, store minerals, and provide for muscle attachment.

2. Broken bones heal when the broken ends contact and a thick band of cells produced by the periosteum forms.

3. Movable joints move freely and are pivot, hinge, ball-and-socket, or gliding in type. The skull and pelvic joints in adults do not move and are classified as immovable.

18-2: The Muscular System

1. Muscle contracts to move bones and body parts.

2. Skeletal muscle is voluntary and moves bones. Smooth muscle is involuntary and controls movement in internal organs. Cardiac muscle is involuntary and located only in the heart.

3. Muscles contract to move body parts. Muscles pull, never push, body parts. Skeletal muscles work in pairs. When one contracts, the other relaxes.

18-3: Science and Society: Drugs for Fitness?

1. Anabolic steroids build muscle, but the effects of abuse may be threatening to health.

2. Use of anabolic steroids is controversial.

18-4: Skin

1. The epidermis is the outer layer with dead cells on the surface. Bottom layers of epidermis give rise to new skin cells. Melanin is found in the inner layers. The dermis is the inner layer with hair follicles, nails, nerves, sweat and oil glands, and blood vessels.

2. Protection, water retention, storage of vitamin D, and helping with body temperature are the skin's jobs.

3. Undamaged epidermis destroys bacteria and can form protective scabs.

KEY SCIENCE WORDS

a. **anabolic steroids**
b. **cardiac muscle**
c. **cartilage**
d. **dermis**
e. **epidermis**
f. **fracture**
g. **immovable joint**
h. **involuntary muscles**
i. **joint**
j. **ligament**
k. **marrow**
l. **melanin**
m. **movable joint**
n. **muscle**
o. **periosteum**
p. **skeletal muscles**
q. **skeletal system**
r. **smooth muscles**
s. **tendons**
t. **voluntary muscles**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. tough outer covering of bone
2. internal body framework
3. tissue or organ that contracts
4. a broken bone
5. voluntary muscles
6. involuntary heart muscle
7. outer layer of skin
8. skin pigment
9. holds bones together
10. attach muscles to bones

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. ______ bone is the most solid form of bone.
   a. Compact **c.** Spongy
   b. Periosteum **d.** Marrow
2. Blood cells are made in the ______.
   a. compact bone **c.** spongy bone
   b. periosteum **d.** marrow
3. Minerals are stored in ______.
   a. bone **c.** muscle
   b. skin **d.** blood
4. ______ covers the ends of bones.
   a. Cartilage **c.** Ligaments
   b. Tendons **d.** Muscle
5. Immovable joints are found ______.
   a. at the elbow **c.** in the wrist
   b. at the neck **d.** in the skull
6. The knees and fingers are examples of a ______ joint.
   a. pivot **c.** gliding
   b. hinge **d.** ball-and-joint
7. Vitamin ______ is made in the skin.
   a. A **c.** D
   b. B **d.** K
8. Dead cells are found on the ______.
   a. dermis **c.** epidermis
   b. marrow **d.** periosteum
9. Anabolic steroids are used to promote ______ growth.
   a. blood **c.** nerve
   b. bone **d.** muscle
10. ______ helps retain fluids in the body.
    a. Bone **c.** Skin
    b. Muscle **d.** A steroid

USING LAB SKILLS

11. In the Activity on page 425 you observed the parts of a long bone from a mammal. Obtain a long bone from a flying bird such as a turkey, duck, or goose and compare it to the beef bone. What noticeable modifications for flight are present in the bird bone?
12. In the MINI-Lab on page 435 you noted the water in secretions from the sweat glands. Use the cobalt chloride paper to determine the distribution of sweat glands on the soles of your feet.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Distinguish between the functions of ligaments and tendons.
14. What would result if a person had a disease of the periosteum?
15. In arthritis, cartilage is frequently damaged. Why does movement then become painful?
16. From a coach's point of view, why are there advantages and disadvantages to use of anabolic steroids?
17. Predict what would happen if a person's sweat glands didn't produce sweat.

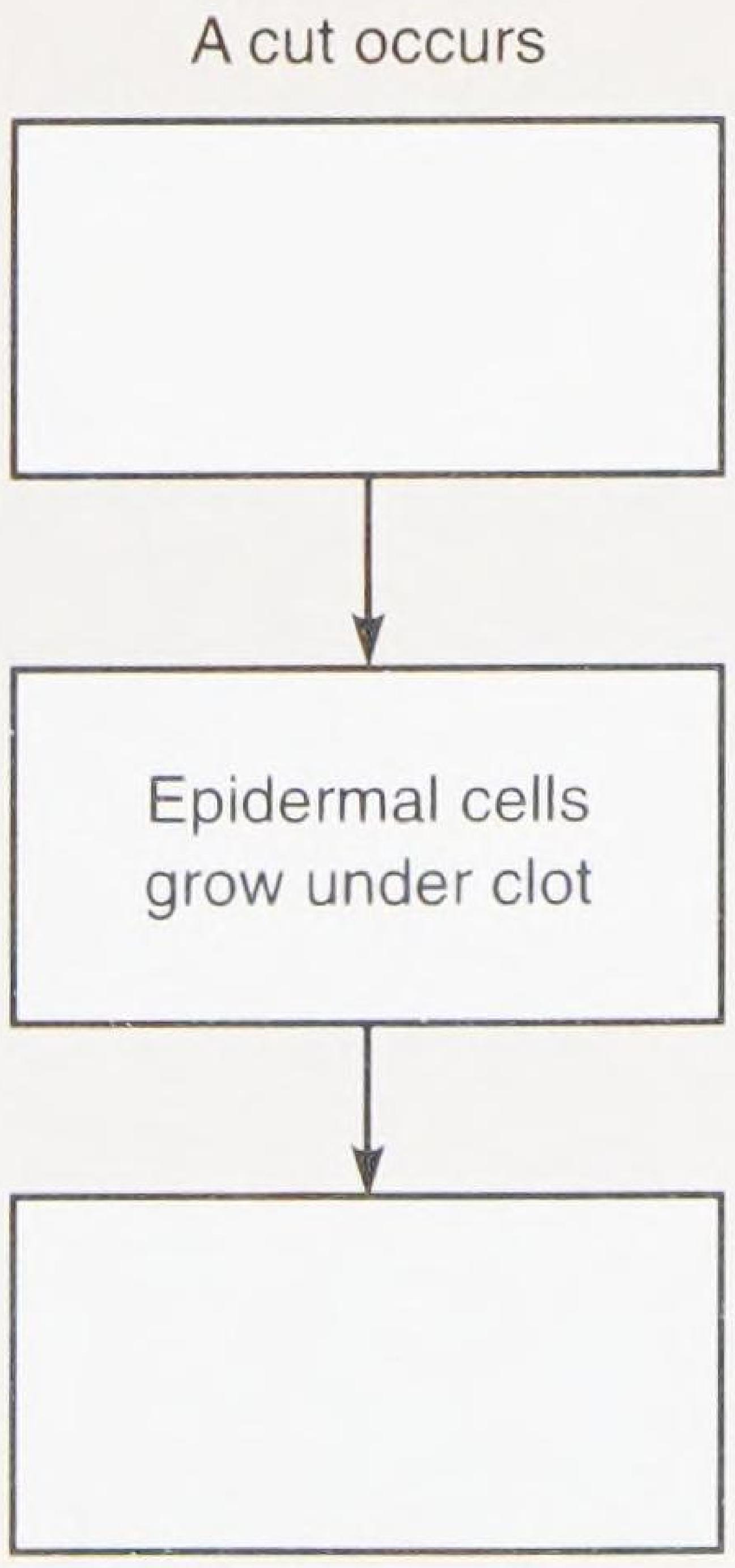
APPLY

18. When might skin not be able to produce enough vitamin D?
19. What effects do sunblocks have on melanin?
20. What would lack of calcium do to bones?
21. Using a microscope, how could you distinguish among the three muscle types?
22. What function of skin in your lower lip changes when a dentist gives you novocaine for a filling in your bottom teeth? Why?

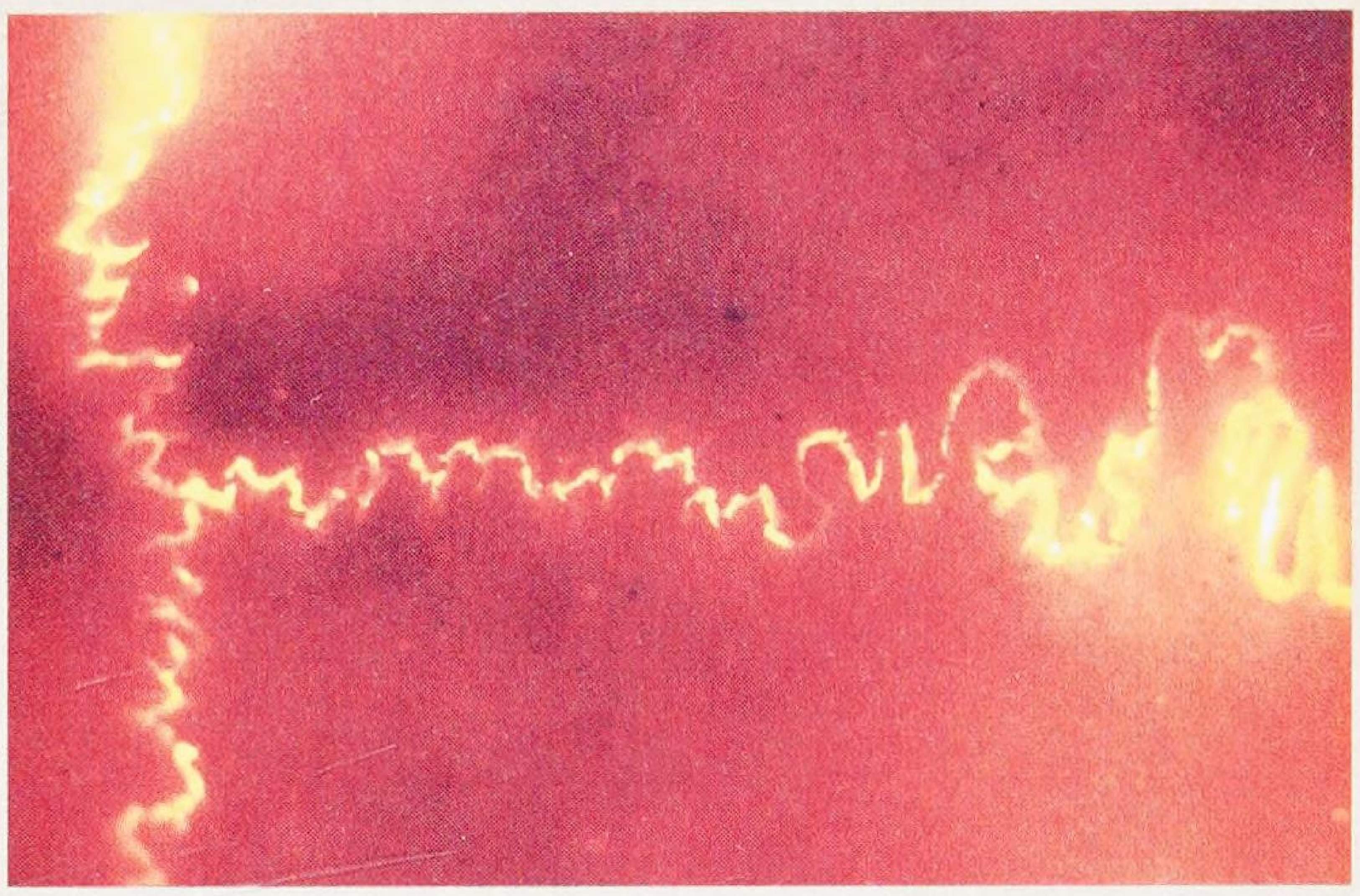
MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Hypothesizing:** Make a hypothesis to explain why a person who "slips a disc" is in pain.
2. **Designing an Experiment:** Design an experiment to compare the heartbeat of athletes and nonathletes in your class.
3. **Hypothesizing:** Make a hypothesis about the distribution of sweat glands throughout the body. Are they evenly distributed?
4. **Concept Mapping:** Complete the events chain concept map to describe scab formation.



5. **Observing and Inferring:** The joints in the skull of a newborn baby are soft, whereas those of a 17-year-old are tightly grown together. Infer why the infant's skull joints are soft.



PROJECTS

1. Find out the differences among first, second, and third degree burns. A local hospital's burn unit or fire department are sources of information on burns. **In your Journal,** draw and describe the differences.
2. How do tanning booths give you a suntan? As a class project, research the safety of this equipment. Present class results and assemble a safety pamphlet that reflects concepts from this chapter.

CHAPTER

19 Nutrients and Digestion

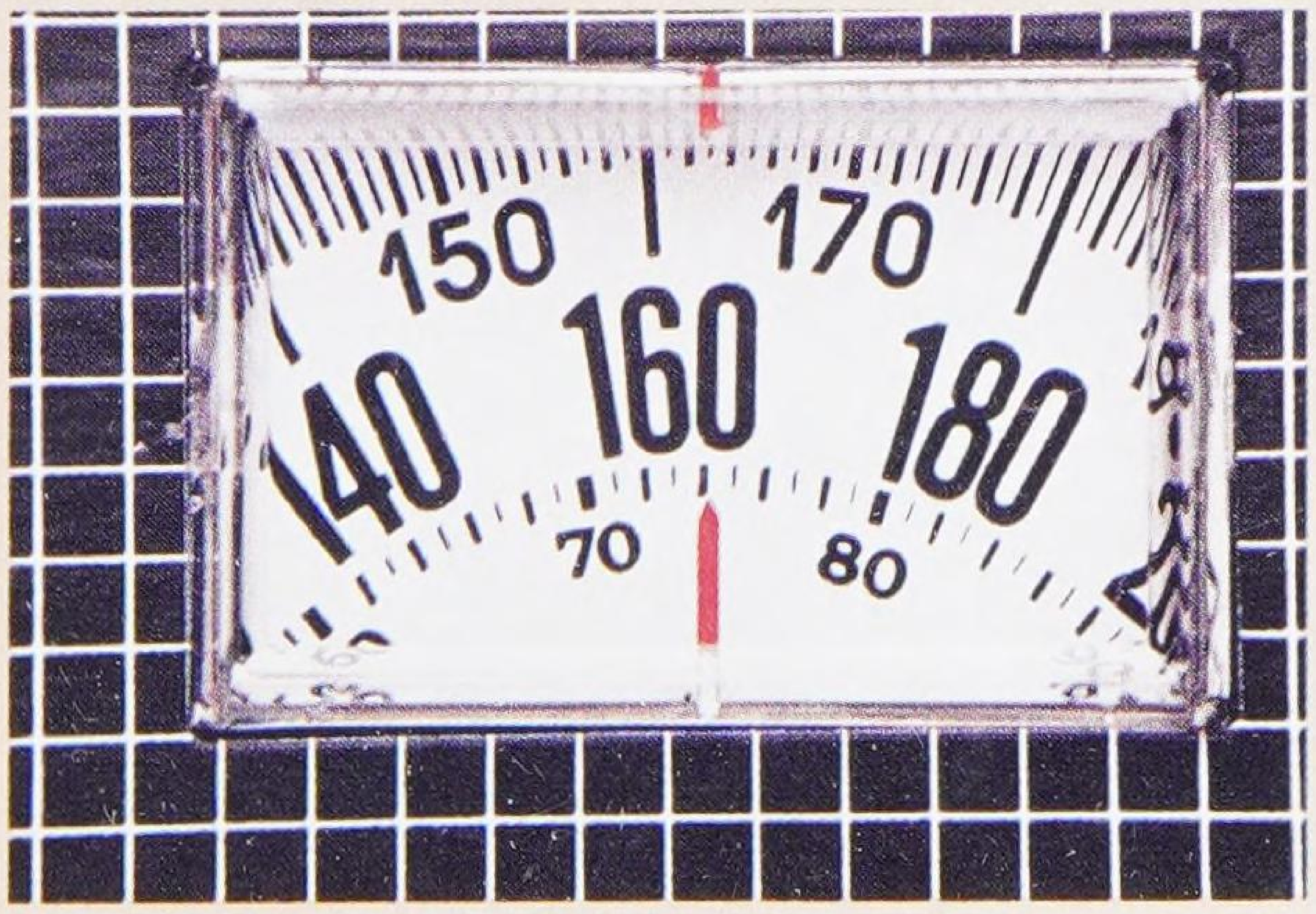
Food that you eat is broken down and absorbed in the soft tissues of your small intestine as shown in the photograph on page 440. Energy from this food is measured in kilocalories. You know these simply as calories. How many calories do you use each day?

FIND OUT!

Calculate the rate at which your body uses energy.

Males use about 1.0 calorie per kilogram (kg) of body mass per hour. Females burn 0.9 calorie per kg of body mass per hour.

1. Convert your mass in pounds to kilograms.
   Pounds ÷ 2.2 lbs/kg = kg
2. Multiply your mass by either 1.0 or 0.9 based on your sex. Your answer is how much energy (cal) you use per hour.
3. Multiply the calories used in one hour by 24 (hours per day). Your answer is the number of calories you burn per day.



Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 19-1 Nutrition
- Why Do You Eat?
- Food Groups

Section 19-2 Your Digestive System
- Processing Food
- In Your Mouth
- In Your Stomach
- In Your Small Intestine
- In Your Large Intestine

Section 19-3 Science and Society
Eating Disorders
- Are Looks That Important?
- Eating Disorders
- What Can You Do?

Previewing Science Skills

- In the **Skill Builders,** you will make and use tables and observe and infer.
- In the**Activities,** you will predict, experiment, and collect data.
- In the **MINI-Labs,** you will measure in SI and make models.

What's next?

Food that you eat each day gives you the energy you need to live. Find out how your body processes food that supplies you with this energy.

19-1 Nutrition

New Science Words

nutrients
carbohydrates
proteins
amino acids
fats
vitamins
minerals
food group

Objectives

- ▶ List the six classes of nutrients.
- ▶ Describe the importance of each type of nutrient.
- ▶ Explain the relationship between diet and health.

Why Do You Eat?

While eating cereal for breakfast, you've probably read all the ads and offers on the box. You may also have noticed the list of nutrients on the side panel. By law, the amount of each nutrient in the cereal has to be listed for you on the label. You think you're eating toasted corn with raisins, but you're really taking in nutrients. **Nutrients** are substances in foods that provide energy and materials for cell development, growth, and repair.

There are six kinds of nutrients available in food: carbohydrates, proteins, fats, vitamins, minerals, and water. Carbohydrates, proteins, vitamins, and fats are all organic nutrients. In contrast, minerals and water are inorganic. They do not contain carbon. Foods containing carbohydrates, fats, and proteins are usually too complex to be absorbed right away by your body. These substances need to be broken down into simpler molecules before the body can make use of them. In contrast, minerals and water can be absorbed directly into your bloodstream. They don't require digestion or breakdown.

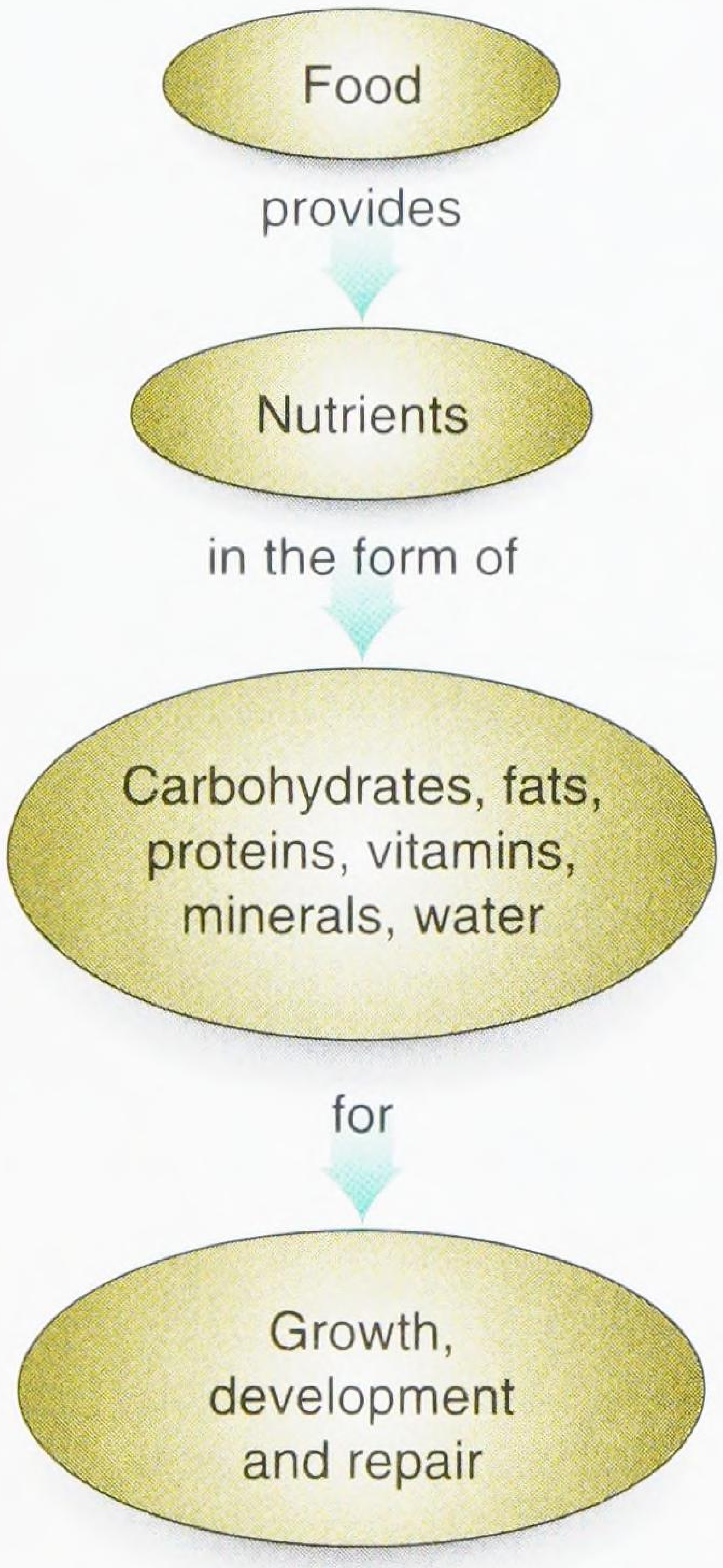

Food
provides
Nutrients
in the form of
Carbohydrates, fats, proteins, vitamins, minerals, water
for
Growth, development and repair

Figure 19-1. Food from a variety of sources provides your body with six types of nutrients.

Carbohydrates

If you look at the panels on several boxes of cereal, you'll notice that carbohydrates are frequently listed first. That means that most of the nutrient in that particular cereal is in carbohydrate form. **Carbohydrates** are the main sources of energy for your body. They contain carbon, hydrogen, and oxygen atoms. During respiration, energy is released when molecules of carbohydrate break down in your cells. Starch, cellulose, and sugar are three types of carbohydrates. Starch and cellulose are complex carbohydrates. Starch is in foods such as potatoes and those made from grains such as pasta. Cellulose occurs in plant cell walls. There are many types of sugars. You're probably most familiar with one called table sugar. Table sugar is an example of a simple carbohydrate. Fruits, honey, and milk are sources of sugar. Your cells use sugar in the form of glucose.

Connect to... Chemistry

There are many kinds of organic compounds, but only carbohydrates have a ratio of two hydrogen atoms to one oxygen atom. What would be the chemical formula for the most simple carbohydrate?

Figure 19-2. Grains and fish are good sources of protein. The grain shown here is amaranth, grown in the tropics.

Proteins

Proteins are nutrients needed throughout your body for growth, as enzymes, and in the replacement and repair of body cells. Proteins are large molecules that contain carbon, hydrogen, oxygen, and nitrogen. A molecule of protein is made up of a large number of subunits or building blocks called **amino acids.** In Chapter 4 you learned that proteins are made according to directions supplied by genes that you inherit. Your body needs 22 different amino acids to be able to construct the proteins needed in your cells. Fourteen of these amino acids can be made in your cells. The eight remaining amino acids are called *essential* amino acids. Your body doesn't have genetic instructions to con-

Did You Know?

Cultures that drink blood as a part of their diet supply some of their nutritional needs for sodium, protein, and iron.

struct them in your cells. Therefore, they have to be supplied through food in your diet. Eggs, milk, and cheese contain all the essential amino acids. Beef, pork, fish, chicken, and nuts supply only some of them. You might be surprised to know that whole grains such as wheat, rice, and soybeans supply many needed amino acids in addition to carbohydrates.

Fats

Fats are nutrients that provide energy and help your body store some vitamins. For good health, your diet should be no more than 30 percent fat. Fats are stored in your body in the form of fat tissue that cushions your internal organs. Carbohydrates supply most people with most of the energy they need, because people eat a lot of carbohydrates. However, a molecule of fat releases more energy than a molecule of carbohydrate. A single molecule of fat breaks down into smaller molecules called fatty acids and glycerol.

There are two types of fats: unsaturated and saturated fats. Plants supply unsaturated fats. Corn, safflower, and soybean oils are all unsaturated fats. Some unsaturated fats are also found in poultry, fish, and nuts. Saturated fats are found in red meats. Saturated fats have been associated with high levels of blood cholesterol that contribute to heart disease. A lot has been written about the bad effects of cholesterol. However, cholesterol does occur normally in all your cell membranes. But, too much cholesterol in your diet causes fat deposits to form on the walls of blood vessels, resulting in a cutoff of blood supply to organs and an increase in blood pressure. Figure 19-3 shows the kind of fat tissue that builds up under the skin.

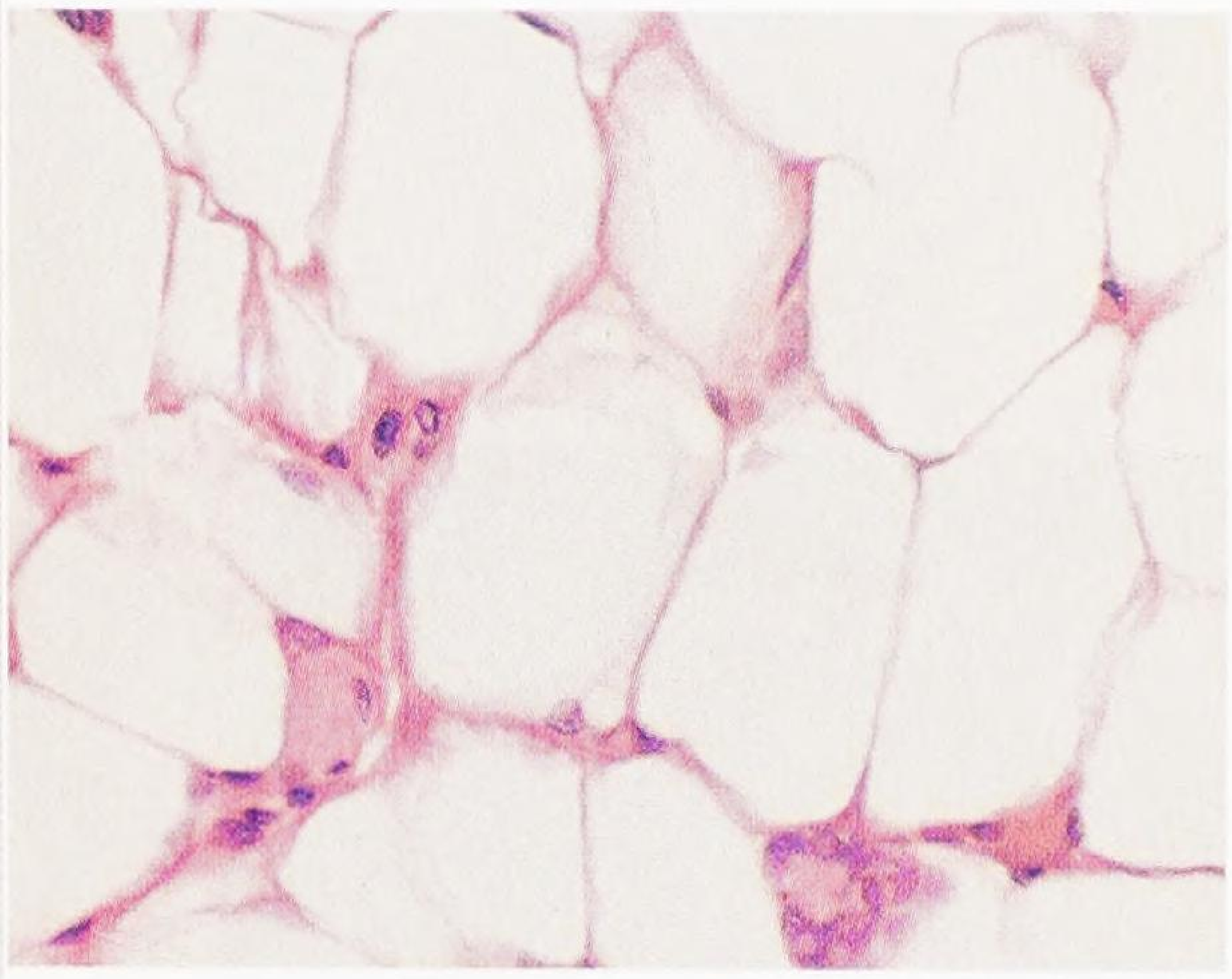


Figure 19-3. Certain cells in your body become filled with fat. The cytoplasm and nucleus get pushed to the edge of the cell.

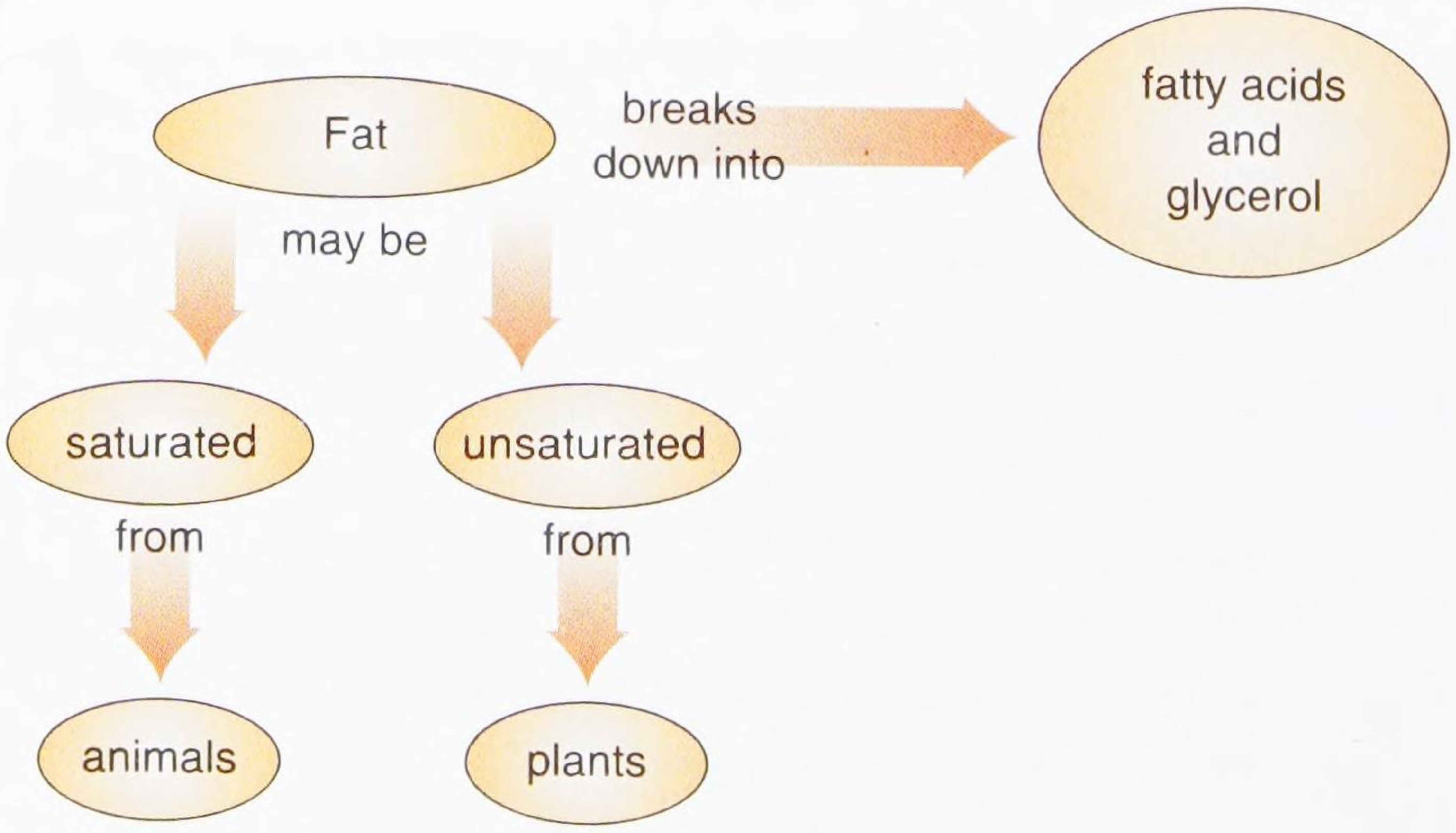


Figure 19-4. In your digestive system, a single molecule of fat breaks down into fatty acids and glycerol.

TECHNOLOGY

Fake Fat

Americans obtain an average of 37 percent of their daily calorie intake from fat. Fats and sodium often make the food taste great. Various companies are experimenting with fat substitutes so that people can eat rich-tasting foods, without gaining weight.

Foods using fat substitutes or fake fats have to be lower in calories than real fat and still try to maintain the taste of fat-rich foods. Some fake fats are useful in frozen products, but can't be used to cook with because they break down when heated. Many fail taste tests.

One fat substitute, however, is waiting approval by the Food and Drug Administration. It is composed of table sugar molecules attached to fatty acid molecules. It looks like fat and tastes like it, too. This product passes through the digestive system without being absorbed. In addition, it can be used in cooking and has no calories.

Think Critically: What are the possible disadvantages of using fake fat in your diet?

Vitamins

Vitamins are essential, organic nutrients needed in small quantities to help your body use other nutrients. For instance, vitamin D is needed for bone cells to use the mineral calcium. In general, vitamins promote growth and regulate many body functions.

Most foods supply some vitamins, but no one food has them all. Eating a variety of foods usually supplies all the vitamins the body needs. Some vitamins dissolve easily in water and are called water-soluble vitamins. Others dissolve only in fat and are called fat-soluble vitamins. Although some people feel that taking extra vitamins is helpful, normally eating a balanced diet is sufficient to give your body all the vitamins it needs. Vitamins are found in a variety of meats and vegetables. Your body makes vitamin D when your skin is exposed to sunlight. Some vitamin K is made with the help of bacteria that live in your large intestine. Table 19-1, on the next page, lists major vitamins, their effects on your health, and some of the foods that provide them.

In Your JOURNAL

What might be the disadvantage of substituting vitamin pills for a proper diet? Find out which vitamins are water soluble and which are fat soluble. **In your Journal,** state why vitamin pills are not a substitute for a balanced diet.

What are two types of vitamins?

Table 19-1

VITAMINS		
Vitamin	**Health Effect**	**Food Sources**
A	growth, good eyesight, healthy skin	green/yellow vegetables, liver and fish liver oils, milk, yellow fruit
B (thiamine, riboflavin, niacin, B_6, B_{12})	growth, healthy nervous system, use of carbohydrates, red blood cell production	meat, eggs, milk, cereal grains, green vegetables
C	growth, healthy bones and teeth, wound healing	citrus fruits, tomatoes, green leafy vegetables
D	absorption of calcium and phosphorus by bones and teeth	milk, eggs, fish
E	formation of cell membranes	vegetable oils, eggs, grains
K	blood clotting, wound healing	green leafy vegetables, egg yolks, tomatoes

Minerals

Minerals are inorganic nutrients that regulate many chemical reactions in your body. Minerals are chemical elements such as phosphorus. About 14 elements are used by your body for building cells for chemical reactions in cells, for sending nerve impulses throughout your body, and for carrying oxygen to body cells. Minerals used in the largest amounts in your body are given in Table 19-2. These include calcium, phosphorus, potassium, and sodium. Some minerals, called trace minerals, are required in only very small amounts. Trace minerals include iron, copper, and iodine.

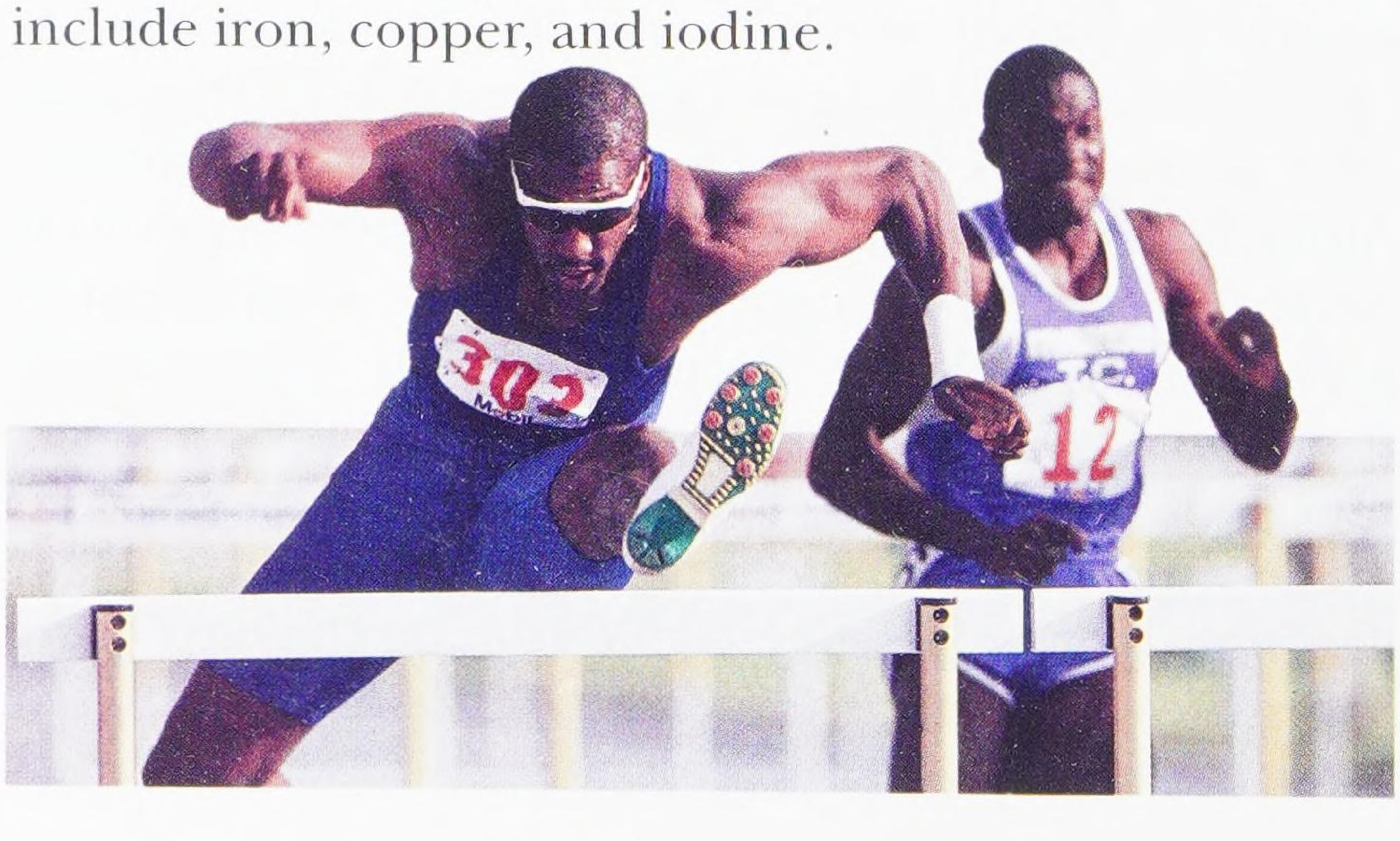


Figure 19-5. Minerals are needed for healthy bones and muscle contraction.

Water

You don't have to be lost in a desert to know how important water is for your body. Next to oxygen, water is the most vital factor for survival. You could live a few weeks without food, but only a few days without water. Most of the nutrients you have studied in this chapter can't be used by your body unless they are carried in a solution. This means that they have to be dissolved in water. Water enables chemical reactions to take place in cells.

Where is water found in the body?

Your body is about 60 percent water. This water is found in and around cells and in plasma and lymph. Water removes waste products from cells. Wastes dissolved in water leave your body as urine or perspiration. To balance water lost each day, you need to drink about two liters of liquids. But don't think that you have to drink just water to keep your cells supplied. Most foods have more water in them than you realize. An apple is about 80 percent water and many meats are as much as 90 percent water.

Table 19-2

MINERALS

Mineral	Health Effect	Food Sources
Calcium	strong bones and teeth, blood clotting, muscle and nerve activity	milk, eggs, green leafy vegetables
Phosphorus	strong bones and teeth, muscle contraction, stores energy	cheese, meat, cereal
Potassium	balance of water in cells, nerve impulse conduction	bananas, potatoes, nuts, meat
Sodium	fluid balance in tissues, nerve impulse conduction	meat, milk, cheese, salt, beets, carrots
Iron	carries oxygen in hemoglobin in red blood cells	raisins, beans, spinach, eggs
Iodine	thyroid activity, stimulates metabolism	seafood, iodized salt

MINI-Lab

How much water?

Using a pan balance, find the mass of an empty 200 mL beaker. Fill the beaker with sliced celery or sliced carrots and find the mass of the filled beaker. *Estimate* the amount of water you think is in the vegetable. Obtain permission to dry the vegetable pieces overnight in an oven on a flat tray at very low heat. Use an oven mitt to remove the tray. Allow the tray and vegetables to cool. Then *determine* the mass of the dried vegetables. How much water was in the fresh vegetables?

Table 19-3

WATER LOSS

Through	Amount (mL/day)
Exhaled air	350
Feces	150
Skin (mostly as sweat)	500
Excretory system	1800

Your body also loses about two liters of water every day through excretion, perspiration, and respiration. Table 19-3 shows how water is lost from the body. The body is equipped to maintain its fluid content, however. When your body needs water, it sends messages to your brain. A feeling of thirst develops. Drinking a glass of water usually restores the body's homeostasis, and the signal to the brain stops.

Food Groups

Because no one food has all the nutrients, you need to eat a variety of foods. Nutritionists have developed a simple system to help people plan meals that include all the nutrients required for good health. This system involves making choices from foods that have been classified according to the major nutrients they contain.

Foods that contain the same nutrients belong to a **food group.** Figure 19-6 shows the four basic food groups with the serving suggestions for maintaining health. The groups are: the milk group, the fruit and vegetable group, the grain group, and the meat group. Eating a certain amount from each food group will supply your body with the nutrients it needs for energy and growth. Of course, most people eat from these food groups in a combined form. Combinations of food contain ingredients from

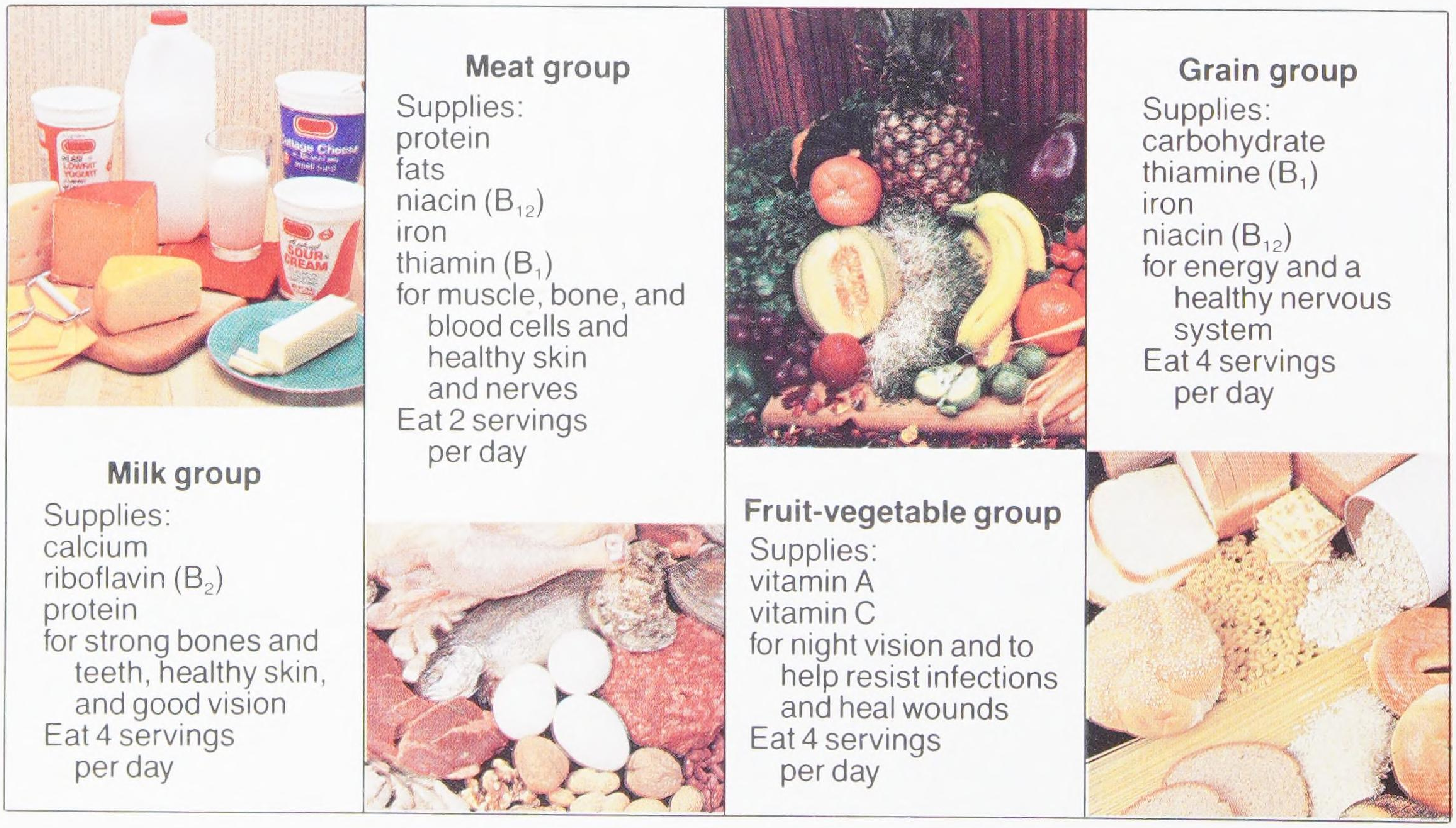


Figure 19-6. Selections made from food groups will provide needed nutrients.

Milk group

Supplies:
calcium
riboflavin (B_2)
protein
for strong bones and teeth, healthy skin, and good vision
Eat 4 servings per day

Meat group

Supplies:
protein
fats
niacin (B_{12})
iron
thiamin (B_1)
for muscle, bone, and blood cells and healthy skin and nerves
Eat 2 servings per day

Fruit-vegetable group

Supplies:
vitamin A
vitamin C
for night vision and to help resist infections and heal wounds
Eat 4 servings per day

Grain group

Supplies:
carbohydrate
thiamine (B_1)
iron
niacin (B_{12})
for energy and a healthy nervous system
Eat 4 servings per day

PROBLEM SOLVING

The Big Race

Jerry is a long-distance runner. He plans to run the Boston Marathon on Patriots' Day. This world-famous race is more than 42 kilometers. His mother asked him to choose one of the following menus for dinner the night before the big race.

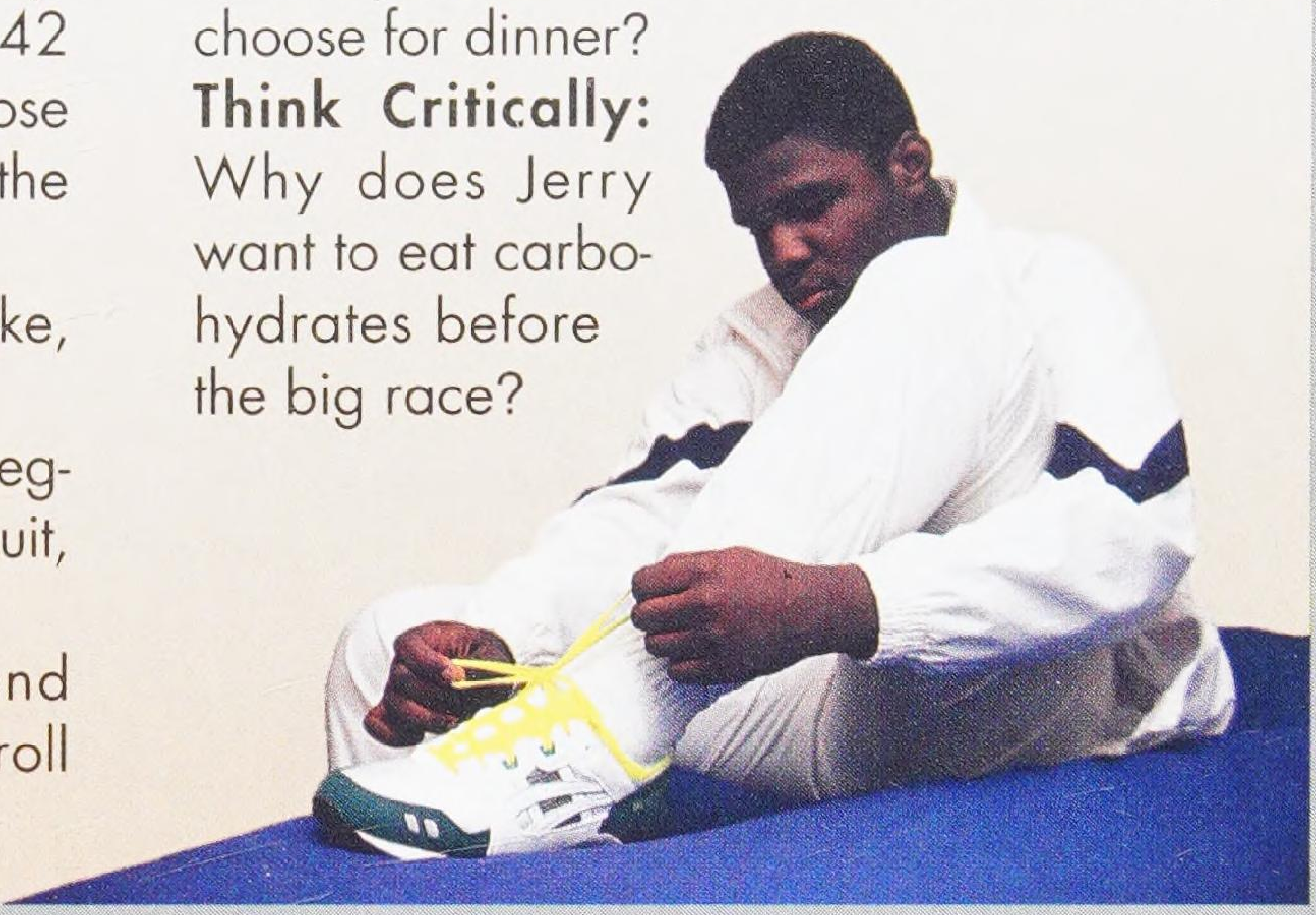
a) hamburger, french fries, chocolate cake, a large glass of cola

b) spaghetti with tomato sauce, fresh vegetable salad, whole wheat roll, fresh fruit, a large glass of water

c) fried chicken, mashed potatoes and gravy, broccoli with cheese sauce, roll and butter, and ice cream.

Jerry wants a meal with a lot of complex carbohydrates. Which menu should Jerry choose for dinner?

Think Critically: Why does Jerry want to eat carbohydrates before the big race?



more than one food group and supply the same nutrients as the foods they contain. Examples of food group combinations include chili and macaroni and cheese.

SECTION REVIEW

1. List six classes of nutrients and give one example of a food source for each.
2. Describe a major function of each class of nutrients.
3. Discuss the relationship between your diet and your health.
4. Explain the importance of water in the body.
5. **Apply:** What foods from each food group would provide a balanced breakfast? Explain your choices.
6. **Connect to Earth Science:** Find out about the source of trace minerals essential for the normal functions of the human body.

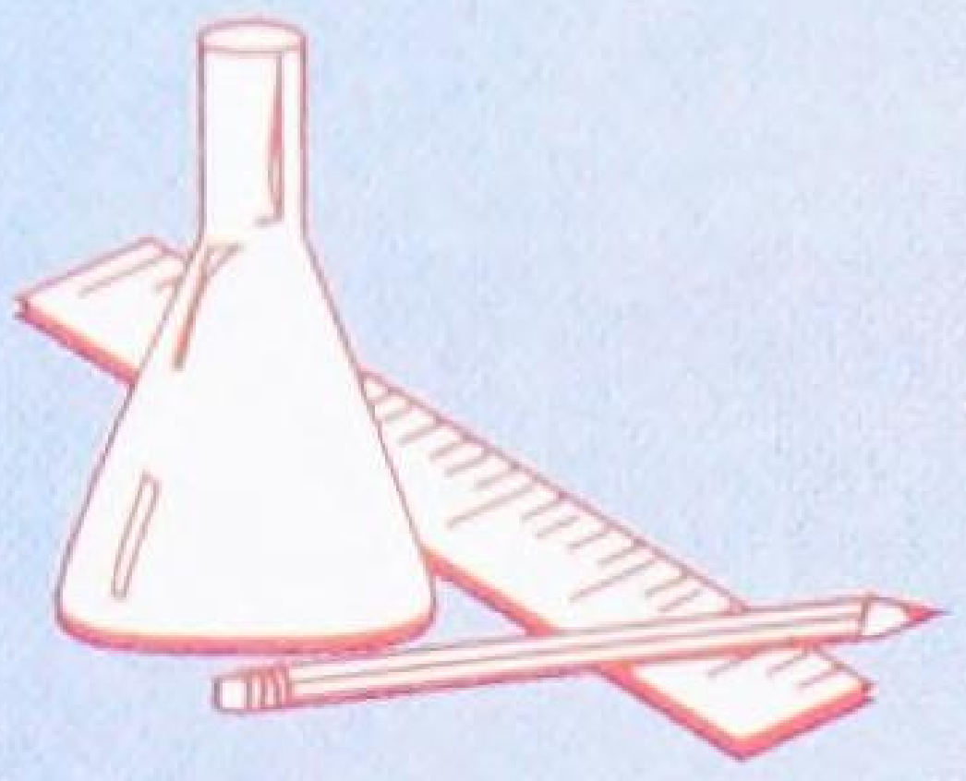
EcoTip

Eat lower on the food chain by consuming more vegetables and fruits.

Skill Builder

Making and Using Tables

Use the information in Table 19-1 and Table 19-2 to determine the vitamins and minerals needed for healthy bones. If you need help, refer to Making and Using Tables in the **Skill Handbook** on page 690.



ACTIVITY 19-1

Identifying Vitamin C Content

Problem: *Which juices contain vitamin C?*

Materials

- indophenol solution
- graduated cylinder
- glass marking pencil
- 10 test tubes
- test-tube rack
- 10 dropping bottles containing water, orange juice, pineapple juice, apple juice, lemon juice, tomato juice, cranberry juice, carrot juice, lime juice, mixed vegetable juice

Procedure

1. Make a data table like the one shown to record your observations.
2. Label the test tubes 1 through 10.
3. Predict which juices contain vitamin C. Record your predictions in your table.
4. Measure 5 mL of indophenol into each of the 10 test tubes. **CAUTION:** *Wear your goggles and apron.* Indophenol is a blue liquid that turns colorless when vitamin C is present. The more vitamin C in a juice, the less juice it takes to turn indophenol colorless.
5. Add 20 drops of water to test tube 1. Record your observations.
6. Begin adding orange juice, one drop at a time, to test tube 2.
7. Record the number of drops needed to turn indophenol colorless.
8. Use Steps 6 and 7 to test the other juices.

Data and Observations

Test tube	Juice	Prediction (yes or no)	Number of drops
1	water		
2	orange		
3	pineapple		
4	apple		
5	lemon		
6	tomato		
7	cranberry		
8	carrot		
9	lime		
10	vegetable		

Analyze

1. What was the purpose of test tube 1?
2. Which juice did not contain vitamin C?
3. Does the amount of vitamin C vary in fruit juices?

Conclude and Apply

4. What is the best way to take in vitamins?
5. Suggest why scurvy, a deficiency of vitamin C, is uncommon today.

CRANBERRY JUICE COCKTAIL
Pineapple Juice
1
2
3
4

Your Digestive System 19-2

Objectives

- Distinguish between mechanical and chemical digestion.
- Name the organs of the digestive system and describe what takes place in each.
- Explain how homeostasis is maintained in digestion.

New Science Words

digestion
mechanical digestion
chemical digestion
saliva
peristalsis
chyme
villi

Processing Food

Like the other animals you have studied so far, you are a consumer. The energy you need for life comes from food sources outside yourself. To keep the cells in your body alive, you take in food every day. Food is processed in your body in four phases: ingestion, digestion, absorption, and elimination. Whether it is a fast-food burger or a home-cooked meal, all the food you eat is treated to the same processes in your body. As soon as it enters your mouth, or is ingested, food begins to be broken down. **Digestion** is the process that breaks food down into small molecules so they can be absorbed, or taken into the cells of your body. Food molecules then move into cells during the process of absorption. Molecules that aren't absorbed are eliminated and pass out of your body as wastes.

Figure 19-7 shows the major organs of your digestive tract: mouth, esophagus (i SAH fuh guhs), stomach, small intestine, large intestine, rectum, and anus. Food passes *through* all of these organs. However, food *doesn't* pass through your liver, pancreas, or gall bladder. These three organs produce or store enzymes and chemicals that help break down food as it passes through the digestive tract.

Digestion is both mechanical and chemical. **Mechanical digestion** takes place when food is chewed and mixed in the mouth, churned in your stomach, and acted on by bile. **Chemical digestion** breaks down large molecules of food into smaller molecules that can be absorbed by cells. Chemical digestion takes place in your mouth, stomach, and small intestine.

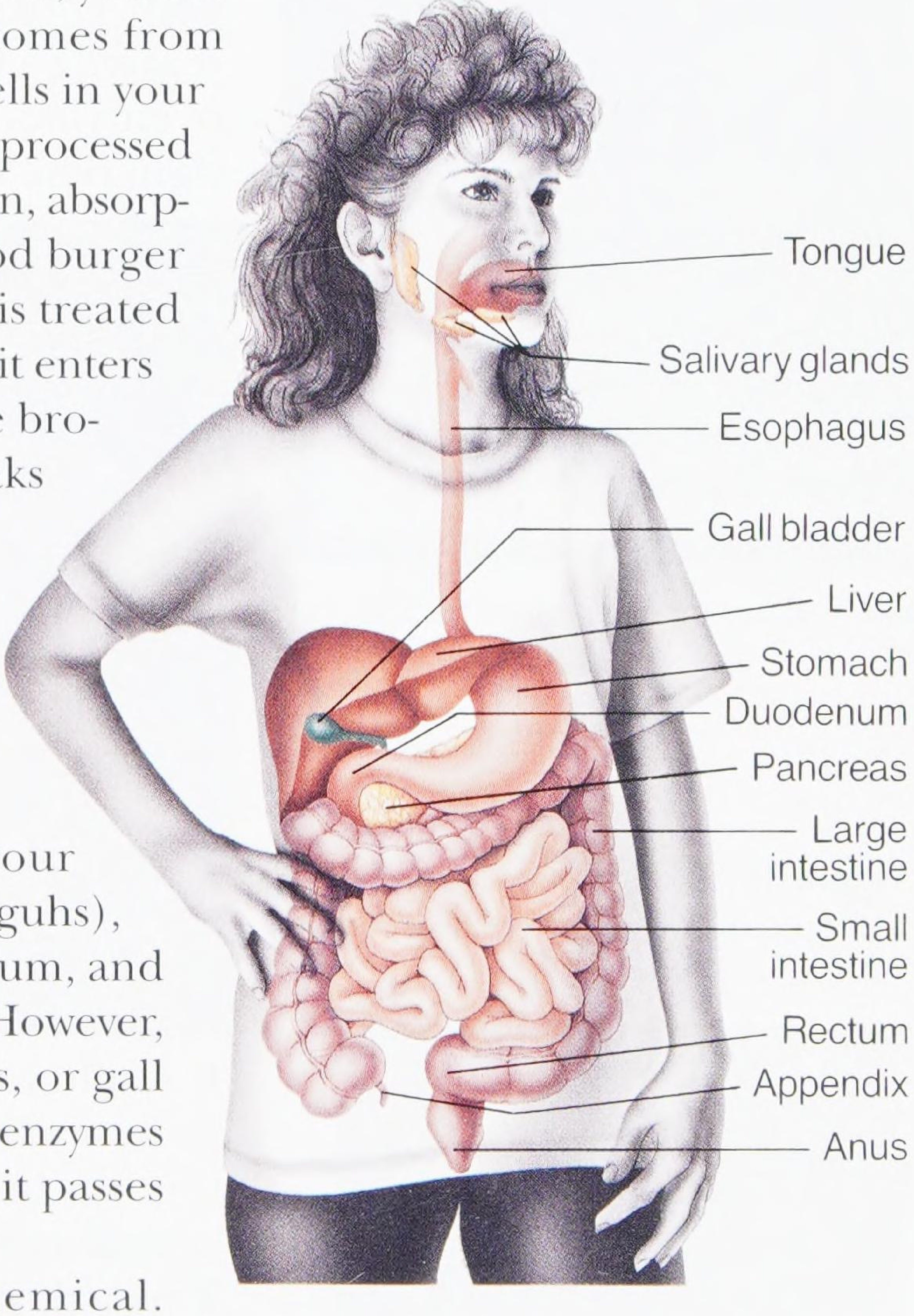


Figure 19-7. The Major Organs for Digestion

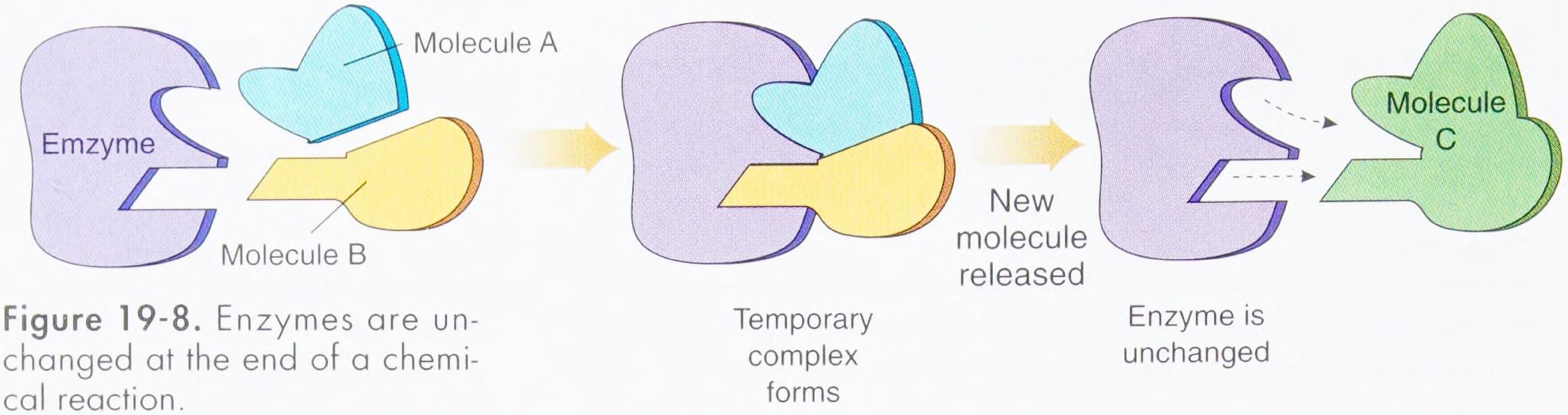


Figure 19-8. Enzymes are unchanged at the end of a chemical reaction.

MINI-Lab

What is the advantage of a rough inner lining?

Cut equal pieces of smooth posterboard and corrugated cardboard. Roll each into a tube. Unroll the tubes. Wet both pieces with water. Which paper has the greater surface area? *Infer* which tube might represent the esophagus, and which the small intestine. How do the two tubes show the differences between the two organs?

Enzymes are proteins that are vital in chemical digestion. An enzyme enters a reaction and helps to join or break up two substances. The enzyme then leaves the reaction without being changed itself. You could say that enzymes are regulators. Some enzymes speed up reactions. Others enable a large molecule to break up without releasing a lot of excess heat energy in the cell. Thousands of enzyme-assisted reactions are taking place in your cells right now. But you aren't at all aware of this activity.

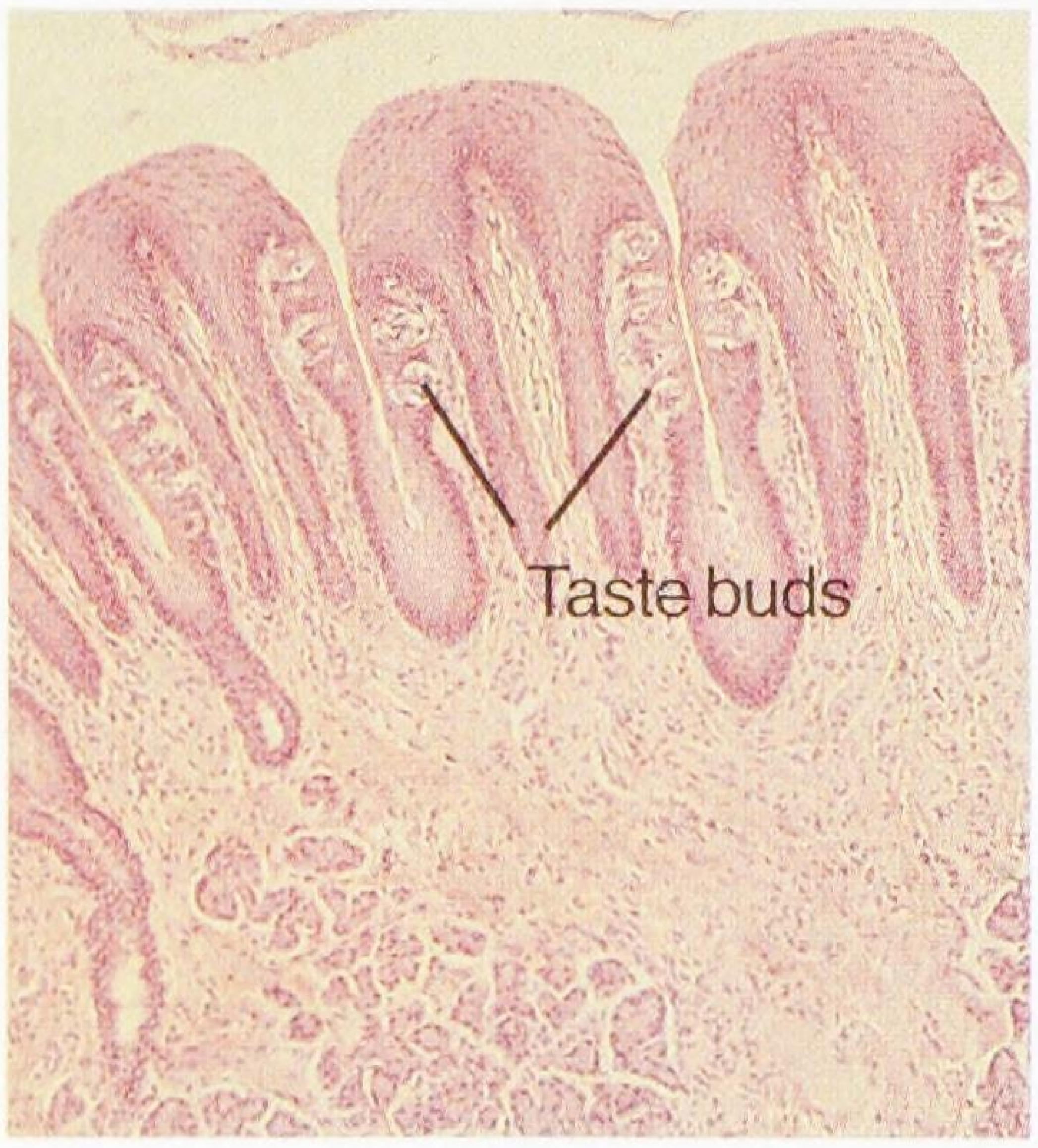
In Your Mouth

The process of digestion begins in your mouth. There, your tongue and teeth mechanically break food up into small pieces. Humans are adapted with several kinds of teeth for cutting, grinding, tearing, and crushing.

Some chemical digestion also starts in your mouth. As you chew, your tongue moves food around and mixes it with a watery substance called **saliva.** Saliva is produced by three types of glands in your mouth that are shown in Figure 19-7. Saliva is made up mostly of water, but it also contains mucus and an enzyme called amylase. Amylase starts the breakdown of starch to sugar in your mouth. Food that is mixed with saliva becomes a soft mass. The food mass is moved to the back of your tongue where it is swallowed and passes into your esophagus. Now the process of ingestion is complete, and the process of digestion has begun.

Your esophagus is a muscular tube about 25 cm long. Through it, food passes to your stomach in about four to eight seconds. No digestion takes place there. Smooth muscles in the walls of the esophagus move food downward by a squeezing action. These waves or contractions, called **peristalsis** (pe ruh STAHL sis), move food along throughout the digestive system. Figure 19-10 shows how peristalsis works.

Figure 19-9. Taste buds help you to figure out whether you like the taste of a particular food.



In Your Stomach

Your stomach is a muscular bag. When it is empty, it is somewhat sausage-shaped with folds on the inside. As food enters from the esophagus, the stomach expands and the folds smooth out. Both mechanical and chemical digestion take place in the stomach. Mechanically, food is mixed by the muscular walls of the stomach and by peristalsis. Food is also mixed with strong digestive juices. Hydrochloric acid and enzymes are made by cells in the walls of the stomach. The stomach also produces mucus that lubricates the food, making it more slick. Mucus also protects the stomach itself from the strong digestive juices. Food moves through your stomach in about four hours. At the end of this time, it doesn't look like food anymore, but has been changed to a thin, watery liquid called **chyme**. Little by little, chyme moves out of your stomach and into your small intestine.

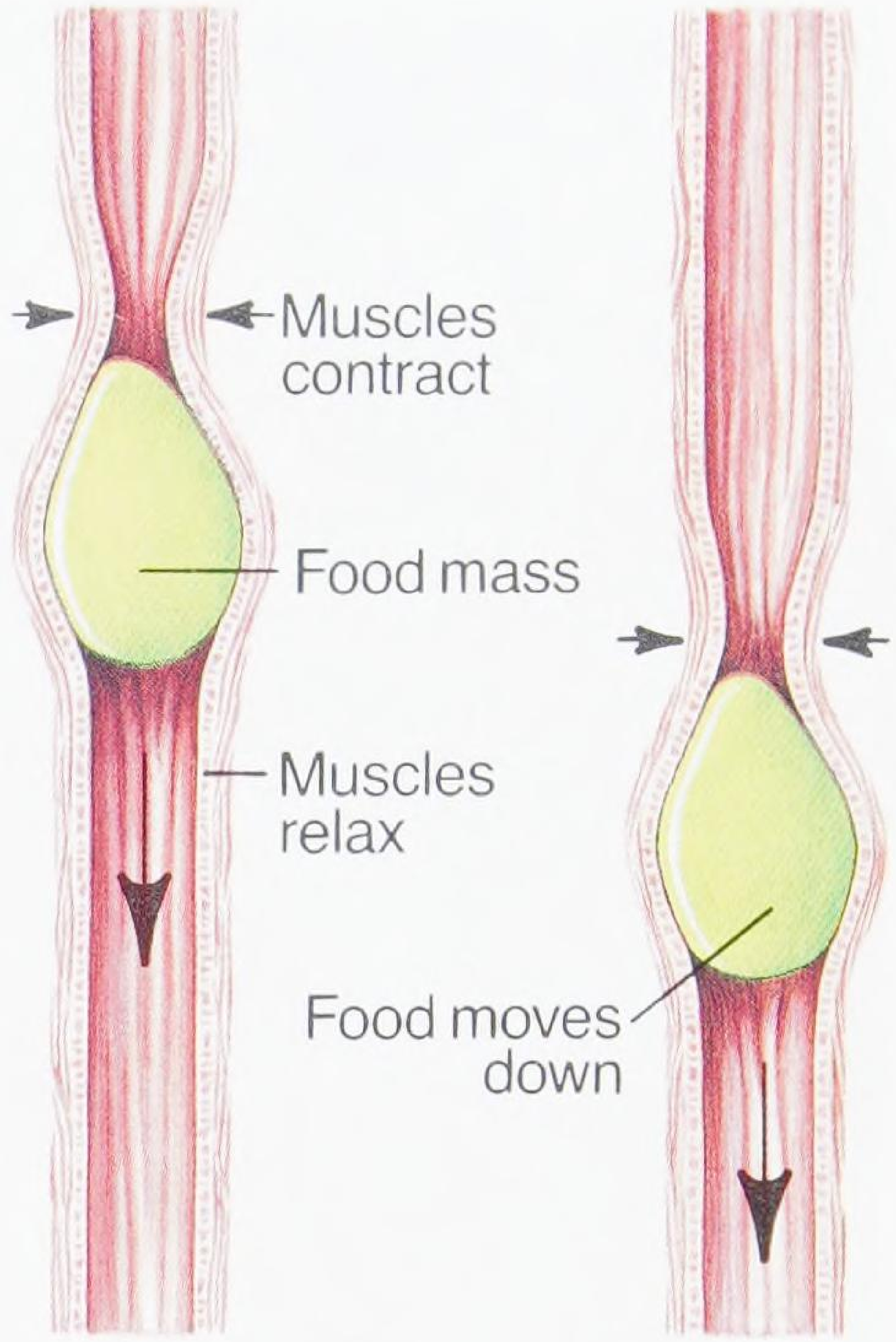


Figure 19-10. During peristalsis, muscles behind the food contract and push the food forward. Muscles in front of the food relax.

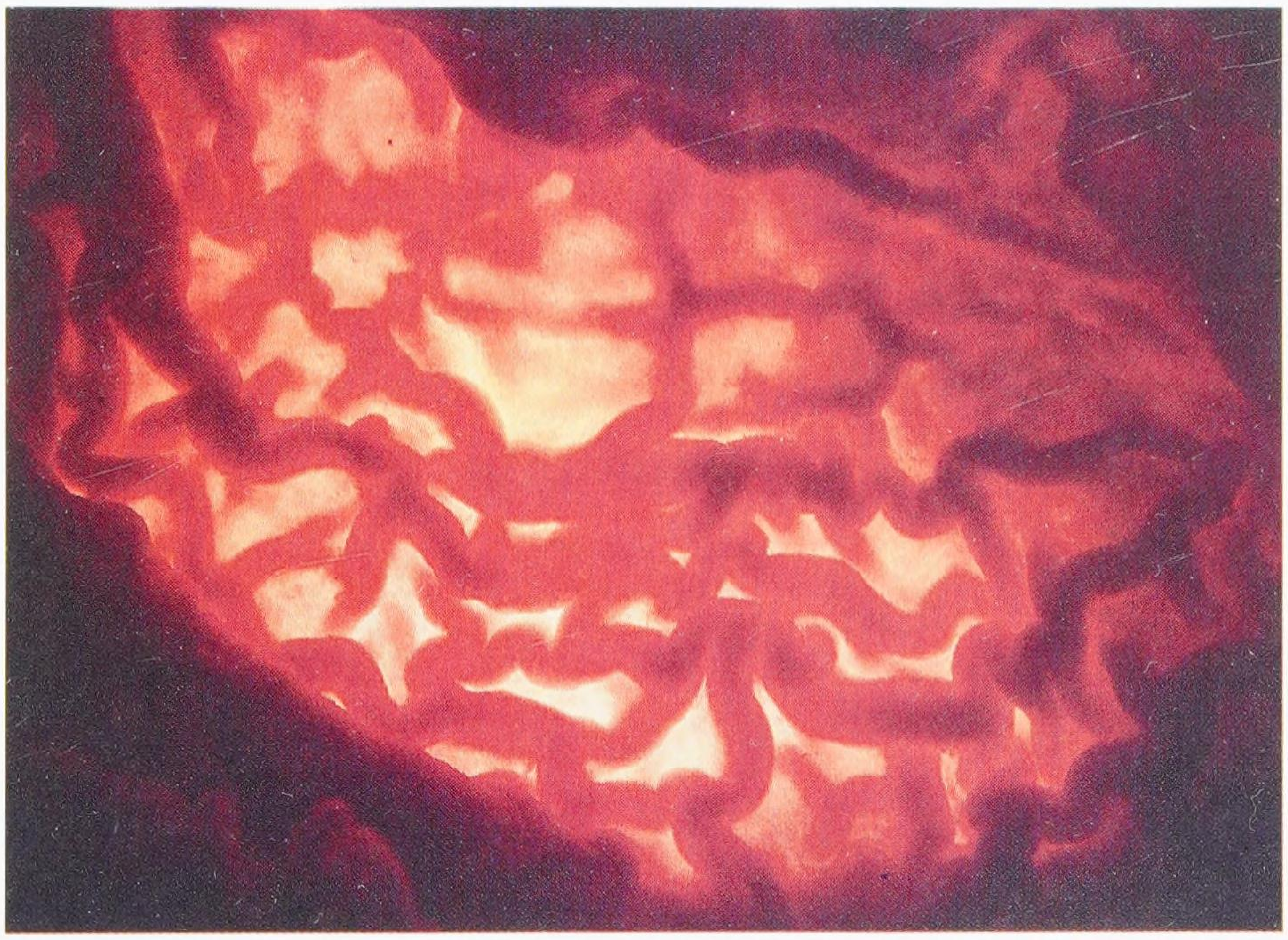


Figure 19-11. Wrinkles in the stomach wall smooth out as it fills with food.

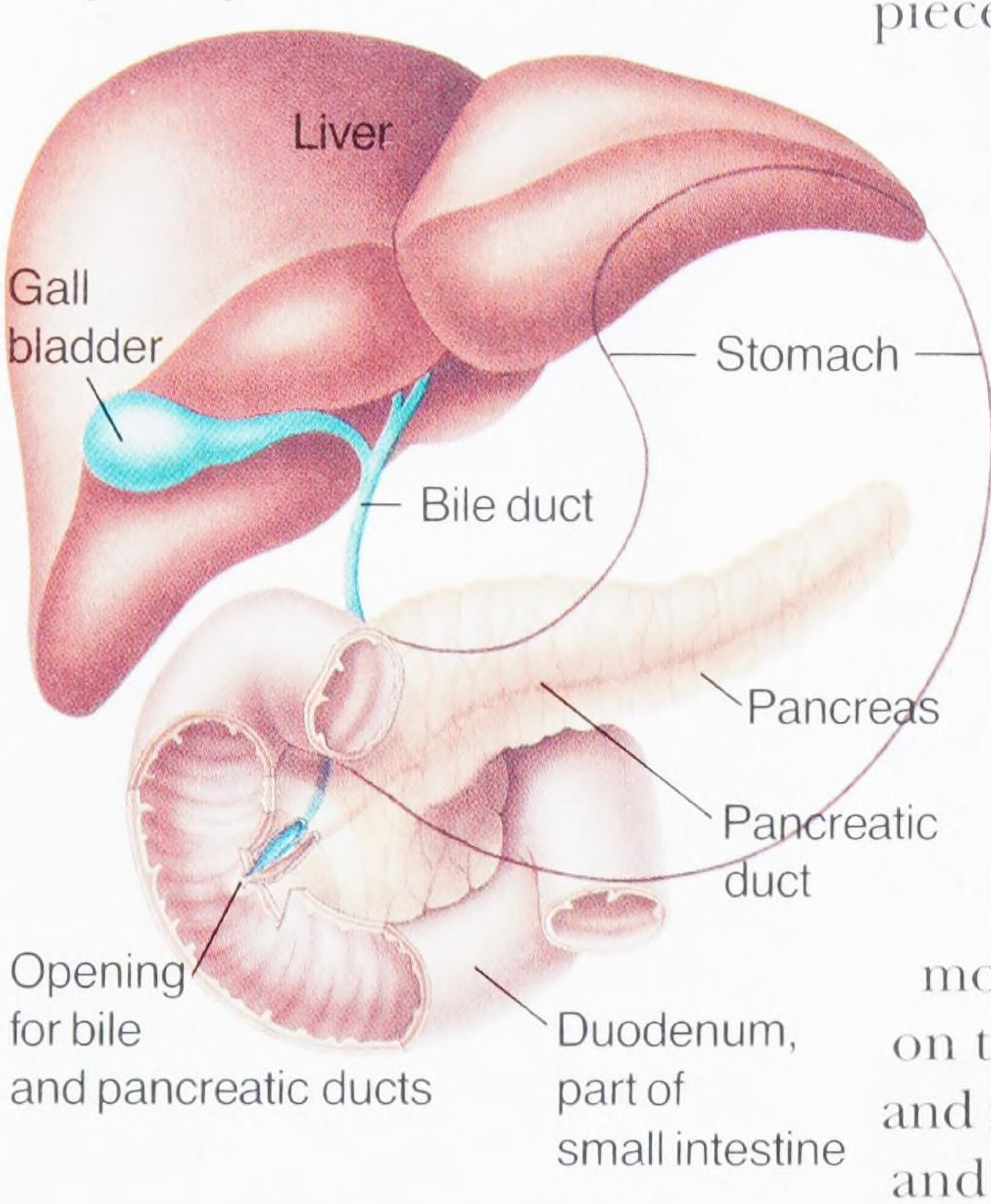
In Your Small Intestine

Your small intestine is small in diameter, but it is nearly seven meters in length. As chyme leaves your stomach, it enters the first part of your small intestine, called the duodenum. The major portion of all digestion takes place in your duodenum. A lot of different things take place here at the same time. Here, digestive juices from the liver and pancreas are added to the mixture. Your liver produces a greenish fluid called bile, which it stores in a

Connect to...
Chemistry

What is a gallstone and how can it be treated?

Figure 19-12. The liver, gall bladder, and pancreas are at the beginning of the small intestine.


Liver
Gall bladder
Stomach
Bile duct
Pancreas
Pancreatic duct
Opening for bile and pancreatic ducts
Duodenum, part of small intestine

small sac called the gall bladder. The acid from the stomach makes large fat particles float to the top of the liquid. Bile physically breaks up these particles into smaller pieces, the way detergent acts on grease on dishes.

Your pancreas makes insulin and substances that stop the action of stomach acid. It also produces enzymes that break down carbohydrates, fats, and proteins still further.

The walls of your small intestine are not smooth like the inside of a garden hose. Rather, they have many ridges and folds. These folds are covered with tiny, fingerlike projections called **villi.** Villi make the surface of the small intestine larger so that there are more places for food to be absorbed. Villi are shown in Figure 19-13.

Where are nutrients absorbed?

By this time, chyme has become a soup of molecules that is ready to be absorbed through the cells on the surface of the villi. Peristalsis continues to move and mix the chyme. In addition, the villi themselves move and are bathed in the soupy liquid. Molecules of nutrients pass by diffusion, osmosis, or active transport into blood vessels in each villus. From there, blood transports the nutrients to all the cells of the body. Peristalsis continues to slowly force the remaining materials that are not absorbed along into the large intestine.

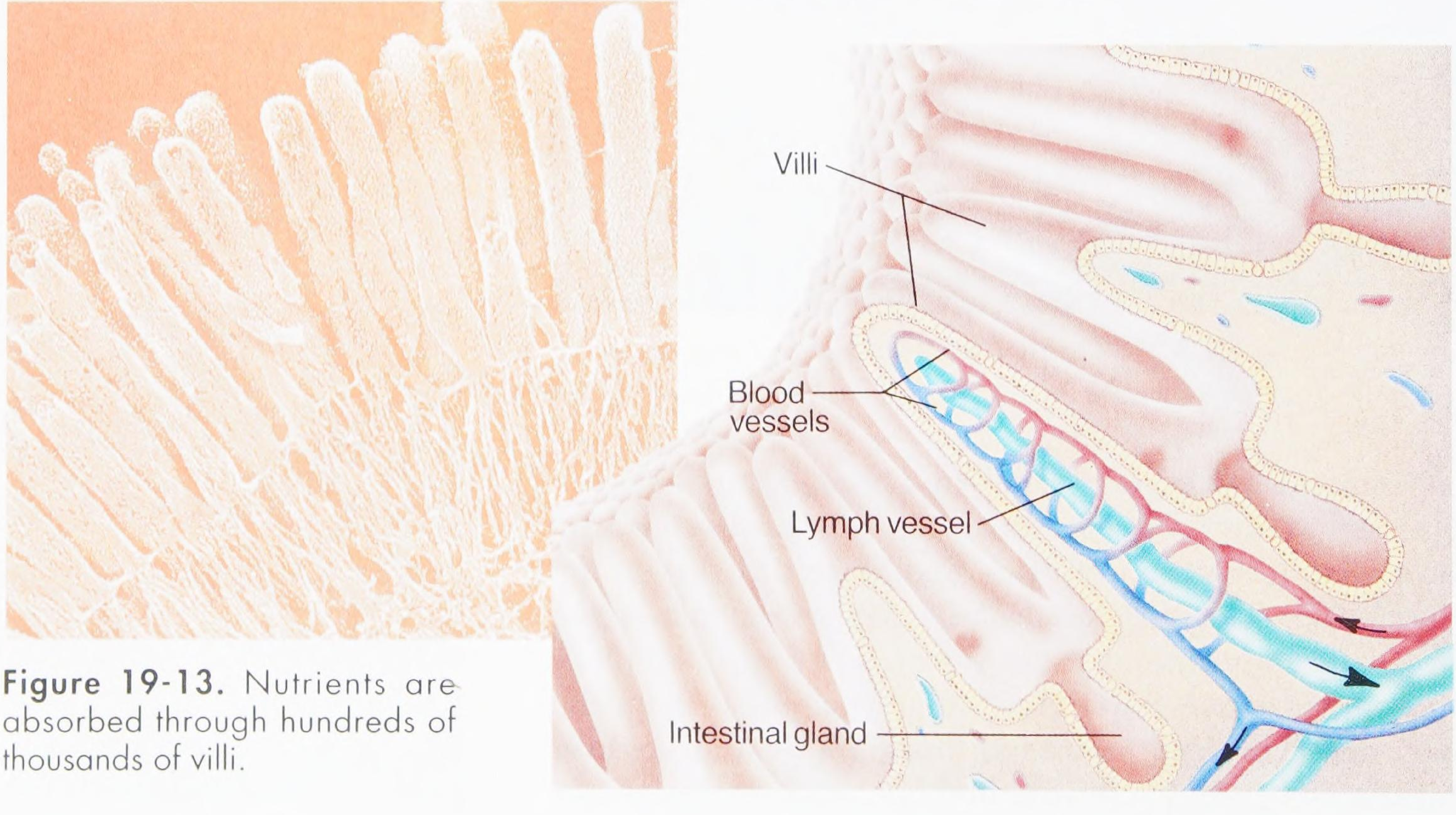

Villi
Blood vessels
Lymph vessel
Intestinal gland

Figure 19-13. Nutrients are absorbed through hundreds of thousands of villi.

In Your Large Intestine

As chyme enters the large intestine, it is still a thin, watery mixture. The main job of the large intestine is to absorb this water from the undigested mass. In doing so, large amounts of water are returned to the body and homeostasis is maintained. Peristalsis slows down somewhat in the large intestine. As a result, chyme may stay in the large intestine as much as three days. During this time, excess water and sodium are absorbed back into the bloodstream. The remaining materials, consisting of undigested cellulose and bacteria, become more solid. Bacteria that live in your large intestine feed on undigested materials like cellulose. This is a symbiotic relationship. The bacteria feed on cellulose and in return they produce several vitamins that you need. Muscles in the rectum and anus control the release of solidified wastes from the body in the form of feces.

Food is processed in your digestive system for the purpose of supplying your body with raw materials for metabolism. These raw materials are in the form of nutrients. Those that are not digested and absorbed are eliminated.

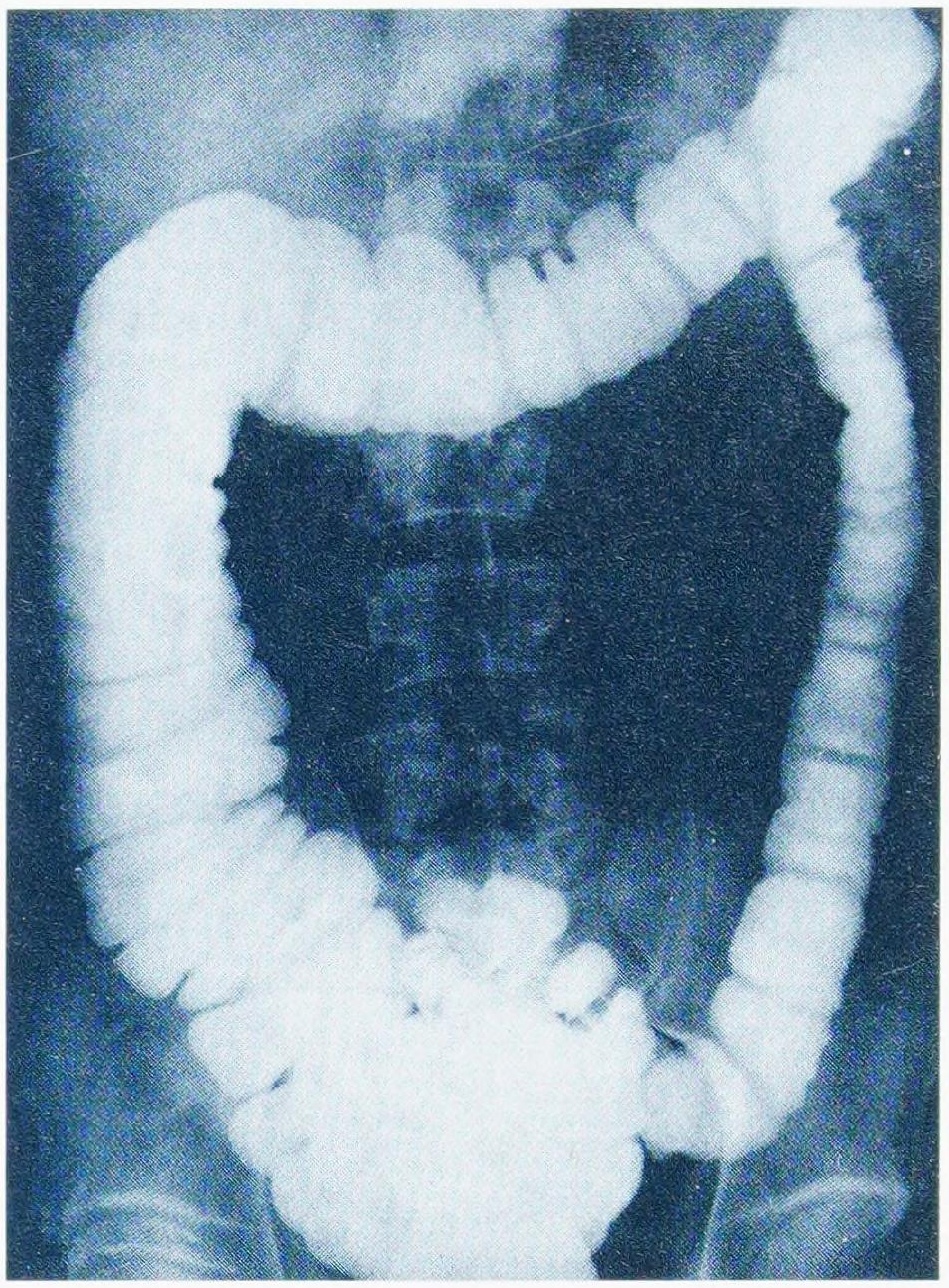


Figure 19-14. The large white area in this X ray is the large intestine.

SECTION REVIEW

1. Name in order the organs through which food passes as it moves through the digestive system.
2. What is the difference between mechanical and chemical digestion?
3. How are the liver, pancreas, and gall bladder related to digestion?
4. How do activities in the large intestine help maintain homeostasis?
5. **Apply:** Crackers contain starch. Explain why a soda cracker held in your mouth for five minutes might begin to taste sweet.
6. **Connect to Physics:** Talk with a dentist to find out about the number of pounds of pressure that can be exerted by the teeth.

Observing and Inferring

Skill Builder

What would happen to food if the pancreas did not secrete its juices into the small intestine? If you need help, refer to Observing and Inferring in the **Skill Handbook** on page 682.

SCIENCE & SOCIETY

19-3 Eating Disorders

New Science Words

anorexia nervosa
bulimia

Objectives

- Name and describe two types of eating disorders.
- Infer the consequences of improper diets associated with eating disorders.

Are Looks That Important?

Have you ever tried on a bathing suit or a pair of jeans in the store only to be disappointed by the fact that they just didn't fit? Do you feel bad when someone comments on your weight? American culture is so fashion conscious that a person's self-worth sometimes becomes dependent on looks. This can be quite a problem because people often rely on food. Sometimes the thought of looking fit and trim is so important that people become obsessed with loosing extra mass as quickly as possible. But often people begin a diet or exercise program, and then return to old eating habits after just a few days.

In Your JOURNAL

The United States Department of Agriculture has composed a list of seven diet goals for improving and maintaining health. Find out what the seven diet goals are. **In your Journal,** write about how people with eating disorders fall short of these goals.

Eating Disorders

Anorexia nervosa and bulimia are two eating disorders that are very dangerous. Although these disorders are more common in adolescent girls, a small percentage of boys have been known to have problems as well.

Connect to... Chemistry

Excessive vomiting can result in the loss of potassium, sodium, and fluids. What are some symptoms of the excessive loss of salts and fluids?

Anorexia nervosa is an eating disorder that involves extreme weight loss to the point of damaging vital organs and even death. It is characterized by preoccupation with eating as little food as possible due to the fear of gaining mass. The goal is to become more attractive, but the opposite effect often results. The extreme lack of food results in starvation-like symptoms, including dry skin and hair, cold hands and feet, and general weakness. There is also a tendency toward increased infections, stress fractures in bones, and weakness of the heart muscle that has resulted in death in some cases.

Bulimia is an eating disorder that involves binging, or eating huge amounts of food in a short period of time, followed by self-induced vomiting, for the purpose of not adding mass to the body. Bulimics also fast and abuse laxatives to move food through their intestines quickly. As a result, the small intestine does not absorb vital nutrients. They sometimes exercise fanatically. Severe dental problems result from exposing the teeth to stomach enzymes and acid during vomiting. Painful ulcers may develop in the mouth and stomach and muscle weakness (the heart is a muscle too) may also develop. In both cases, basic nutritional needs of the body are not satisfied. Over a period of time, the body is starved to death.

Some people may turn and look in admiration at a very thin person. Everyone likes to receive positive comments on his or her appearance. However, the consequences of extreme weight loss or self-induced vomiting make a person look much less attractive. By talking and learning about the problem, victims of eating disorders will come to feel better about themselves and restore themselves to health.

Figure 19-15. Persons with eating disorders may have difficulties with their self-esteem.

What Can You Do?

Do you or does someone that you know have an eating disorder? If so, what can you do? It is often impossible to deal with an eating disorder alone. However, many people are willing to help. Through treatment, the problem can be controlled. The school guidance counselor and nurse are specially trained to help with these problems. Programs have been specifically developed to control these disorders.

SECTION REVIEW

1. Describe two types of eating disorders.
2. What are the effects of eating disorders?
3. **Connect to Chemistry:** Find out about vomiting as a helpful adaptive reflex.

SCIENCE & SOCIETY

You Decide!

Individuals with eating disorders are usually very unwilling to talk about their problems with friends. Maybe they're embarrassed about the condition, or afraid that their families may eventually find out. If you think a friend has an eating disorder, would it be right for you to mention this to the school nurse or guidance counselor? Would you be a caring friend if you chose not to seek help for that person?

ACTIVITY 19-2

Protein Digestion

Problem: *What conditions are necessary for the digestion of protein by pepsin?*

Materials

- unflavored gelatin
- dropper
- two test tubes in rack
- drinking glass
- pepsin powder
- cold water
- graduate cylinder
- marking pen
- dilute hydrochloric acid

Procedure

1. Prepare a data table like the one shown.
2. Prepare the gelatin according to the directions on the package.
3. Pour 10 mL of the gelatin into each of the 2 test tubes. Place the test tubes in a rack and do not disturb them while the gelatin sets.
4. Label one test tube "pepsin with acid," and the other one "pepsin without acid."
5. When the gelatin has set, add 10 drops of the dilute acid to the test tube labeled "pepsin with acid." **CAUTION:** *Always use care when working with acid. Wash your hands thoroughly after pouring the acid.*
6. Sprinkle enough pepsin powder to cover the surface of the gelatin in *both* test tubes.
7. Place the 2 test tubes upright into a drinking glass containing cold water.
8. *Observe* the gelatin every 10 minutes, and record your results in the data table after each observation.

Analyze

1. What did you observe in the test tubes?
2. Was there a difference?
3. Why were the test tubes kept in cold water?
4. What are the constants in this experiment?

Data and Observations

Time minutes	Pepsin with acid	Pepsin without acid
10		
20		
30		
40		
50		

Conclude and Apply

5. Did the acid have any effect on the activity of the pepsin?
6. How does this *relate* to the activity of this enzyme in the stomach?
7. *Infer* why the activity of pepsin stops in the small intestine.

UNFLAVORED
GELATIN
ALL GELATIN PROTEIN
NO SUGAR
4-¼ OZ. ENVELOPES INSIDE
NET WT 1 OZ
28 GRAMS

CHAPTER REVIEW

SUMMARY

19-1: Nutrition

1. Carbohydrates, fats, proteins, minerals, vitamins, and water are the six nutrients found in food.

2. Carbohydrates provide energy; proteins are needed for growth and repair; fats store energy and cushion organs. Vitamins and minerals regulate functions. Water makes up about 60 percent of body mass and is used for a variety of homeostatic functions.

3. Health is affected by the combination of foods that make up a diet.

19-2: Your Digestive System

1. The digestive system breaks food down mechanically by chewing and churning, and chemically, with the help of enzymes, into substances that cells can absorb and use.

2. Food passes through the mouth, esophagus, stomach, small intestine, large intestine, rectum, and out the anus.

3. Homeostasis is maintained by absorption of water in the large intestine.

19-3: Science and Society: Eating Disorders

1. Anorexia nervosa and bulimia are two eating disorders that involve the use of starvation and extreme behaviors to control body mass.

2. Eating disorders result in damage to organs and even death.

KEY SCIENCE WORDS

a. **amino acids**
b. **anorexia nervosa**
c. **bulimia**
d. **carbohydrates**
e. **chemical digestion**
f. **chyme**
g. **digestion**
h. **fats**
i. **food group**
j. **mechanical digestion**
k. **minerals**
l. **nutrients**
m. **peristalsis**
n. **proteins**
o. **saliva**
p. **villi**
q. **vitamins**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. process of breaking down food
2. muscular contractions that move food
3. enzyme-containing fluid in the mouth
4. fingerlike projections in small intestine
5. starch and sugars
6. nutrients that form a cushioning tissue
7. physical breakdown of food
8. inorganic nutrients
9. subunits of proteins
10. eating disorder with induced vomiting

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. Most digestion occurs in the_______.
   a. duodenum **c.** liver
   b. stomach **d.** large intestine
2. The _______ makes bile, which acts on fats.
   a. gall bladder **c.** stomach
   b. liver **d.** small intestine
3. Water is absorbed in the _______.
   a. liver **c.** esophagus
   b. small intestine **d.** large intestine
4. Food does not pass through the _______.
   a. mouth **c.** small intestine
   b. stomach **d.** liver
5. Nutrients that store vitamins are ________.
   a. fats **c.** carbohydrates
   b. proteins **d.** minerals
6. The vitamin not used for growth is _______.
   a. A **c.** C
   b. B **d.** K
7. In the _______, hydrochloric acid is added to the food mass.
   a. mouth **c.** small intestine
   b. stomach **d.** large intestine
8. The _______ produces enzymes that digest proteins, fats, and carbohydrates.
   a. mouth **c.** large intestine
   b. pancreas **d.** gall bladder
9. The food group containing yogurt and cheese is _______.
   a. milk **c.** meat
   b. grain **d.** fruit
10. Carbohydrates are best obtained from _______.
    a. milk **c.** meat
    b. grains **d.** eggs

USING LAB SKILLS

11. The MINI-Lab on page 447 investigates the amount of water in vegetables. Repeat this activity to determine the amount of water in an apple or a pear. What percent of water do these fruits have?
12. In the Activity on page 458 you were asked to determine the conditions necessary for protein digestion by pepsin. Repeat the experiment using a baking soda solution instead of dilute hydrochloric acid. What effect does the baking soda solution have on pepsin activity?

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. What do chewing and the action of bile have in common in the digestive system?
14. Describe the differences among ingestion, digestion, absorption, and elimination.
15. Explain why it isn't really necessary to have food prepared using elaborate recipes. Why do people go to the trouble of cooking meals?
16. List the structures that add enzymes to chyme in the small intestine.
17. Why is a balanced diet important to maintaining homeostasis?

APPLY

18. What types of food would a person whose gall bladder has been removed need to limit in his or her diet? Explain your choice.
19. In what part of the digestive system do antacids work? Explain your choice.

20. Bile's action is similar to soap. Use this information to explain bile working on fats.
21. Vitamins are in two groups: water- or fat-soluble. Which of these might your body retain? Explain your answer.
22. Based on your knowledge of food groups and nutrients, discuss the meaning of the familiar statement: "You are what you eat."

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Making and Using Graphs:** Recommended Dietary Allowances (RDA) are made for the amounts of nutrients people should take in to maintain health. Prepare a bar graph of the percent of RDA of each nutrient from the breakfast product information listed below.

Nutrient	Precent US RDA
Protein	2
Vitamin A	20
Vitamin C	25
Vitamin D	15
Calcium (Ca)	less than 2
Iron (Fe)	25
Zinc (Zn)	15

   Which nutrients are given the greatest percent of the Recommended Dietary Allowance? Could a person on a fat-restricted diet eat this product? Explain.
2. **Sequencing:** In a table, sequence the order of organs through which food passes in the digestive system. Indicate whether ingestion, digestion, absorption, or elimination takes place in the individual organs.
3. **Comparing and Contrasting:** Compare and contrast the location, size and functions of the esophagus, stomach, small intestine, and large intestine.
4. **Sequencing:** Sequence the digestion of a starch, a fat, and a protein, listing where it occurs, what happens, the enzymes used, and the end product of this digestion.
5. **Interpreting Data:** Use a label from a food, list the nutrients and food groups to which each belongs. How many calories are provided by each type?

PROJECTS

1. Research the ingredients of products used in diarrhea and laxatives. Where in the digestive system do these products act and how?
2. Collect labels from breakfast cereals. Compare the amounts of vitamins and minerals. Are the vitamins and minerals a natural part of the ingredients? Were any vitamins or minerals added to make the cereal more healthful?

CHAPTER 20

Your Circulatory System

Strenuous swimming could tire you out, but because your heart constantly pumps blood throughout your body you can continue to swim and play. How do you know that your heart is pumping? Why does it pump faster at certain times?

FIND OUT!

Do this activity to find out about the pumping activity of your heart.

Place your middle and index fingers over one of the carotid arteries in your neck. These arteries are on either side of your trachea. Don't press too hard. You should feel movement as blood is pumped through this artery. This movement is a pulse. Count your carotid pulse rate for 15 seconds, then multiply it by four. This number is your resting heartbeat rate. Now, jog in place for one minute. Take your pulse again. Is there a difference from your resting heart rate? *Hypothesize* why exercise causes a difference in pulse rate.

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 20-1 Circulation
- ▶ Your Cardiovascular System
- ▶ Your Heart
- ▶ Pathways of Circulation
- ▶ Blood Pressure
- ▶ Diseases and Disorders of the Heart

Section 20-2 Blood
- ▶ Functions of Blood
- ▶ Parts of Blood
- ▶ Blood Clotting
- ▶ Blood Types
- ▶ Diseases and Disorders of Blood

Section 20-3 Science and Society
Autologous Blood Transfusions
- ▶ Saving Your Own Blood

Section 20-4 Your Lymphatic System
- ▶ Functions of Your Lymphatic System
- ▶ Lymphatic Organs
- ▶ A Disease of the Lymphatic System

Previewing Science Skills

- ▶ In the **Skill Builders,** you will make a concept map, interpret data, and compare and contrast.
- ▶ In the **Activities,** you will observe, experiment, and collect data.
- ▶ In the **MINI-Labs,** you will diagram and observe and interpret.

What's next?

You've just learned that your pulse can tell you something about your heartbeat rate. In this chapter, you will learn about your heart and your blood and your lymphatic system.

20-1 Circulation

New Science Words

atria
ventricles
pulmonary circulation
arteries
veins
capillaries
systemic circulation
coronary circulation
blood pressure
atherosclerosis
hypertension

Objectives

- Compare arteries, veins, and capillaries.
- Trace the pathway of blood through the chambers of the heart.
- Describe pulmonary and systemic circulation.

Your Cardiovascular System

With a body made up of trillions of cells, you're quite different from a one-celled amoeba living in a puddle of water. But are you really that different? Even though your body is larger and made up of complex systems, the cells in your body have the same needs as the smaller life-form. Both of you need a continuous supply of oxygen and nutrients and a way to remove cell wastes.

An amoeba takes oxygen directly from its watery environment. Nutrients are distributed throughout its single cell by cytoplasmic streaming. In your body, a cardiovascular system moves oxygen and nutrients to cells and removes carbon dioxide and other wastes. *Cardio-* means heart and *vascular* means vessel. This system includes your heart, blood, and kilometers of vessels that carry blood to every part of your body. It is a closed system because blood moves within vessels. How do the parts of this system work?

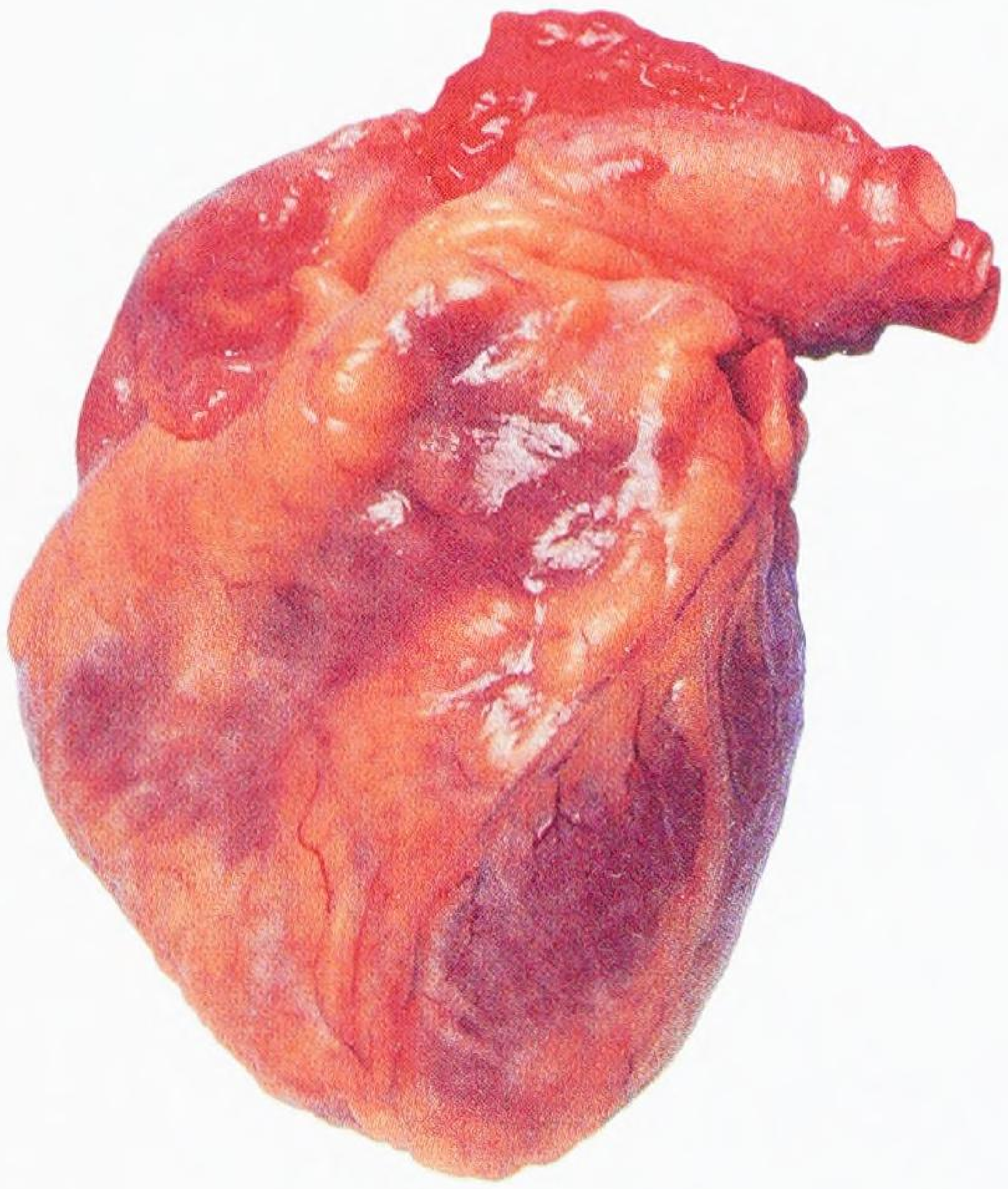


Figure 20-1. A Human Heart

Your Heart

Your heart is a muscular organ about the size of a closed fist. It is located behind your sternum and between your lungs. Your heart has four cavities called chambers. The two upper chambers are the right and left **atria** (AY tree uh) *(singular* atrium). The two lower chambers are the right and left **ventricles** (VEN trih kulz). During a single heartbeat, both atria contract at the same time. Then both ventricles contract at the same time. A valve separates each atrium from the ventricle below it, so that blood flows only from an atrium to a ventricle.

Pathways of Circulation

Three major pathways for blood movement through your circulatory system are called pulmonary (PUL mo ner ee), systemic (sihs TEM ihk), and coronary circulations.

Pulmonary Circulation

Pulmonary circulation is the flow of blood through the heart, to the lungs, and back to the heart. Blood from body cells is high in carbon dioxide and enters the right atrium of the heart through a large vein called the superior vena cava. When the right atrium contracts, this blood is forced into the right ventricle. The right ventricle then contracts, and blood leaves the heart through the pulmonary arteries to go to the lungs. As blood circulates through the lungs, carbon dioxide is exchanged for oxygen. Oxygen-rich blood then returns to the heart through the pulmonary vein and fills up the left atrium. This is the only vein in the body that carries oxygen-rich blood. When the left atrium is full of oxygen-rich blood, it contracts and forces blood into the left ventricle. The final step of this path through the heart occurs when the left ventricle contracts and forces blood up and out of the heart into the largest artery of the body, called the aorta. The aorta carries blood away from the heart to many branching arteries that distribute it to all

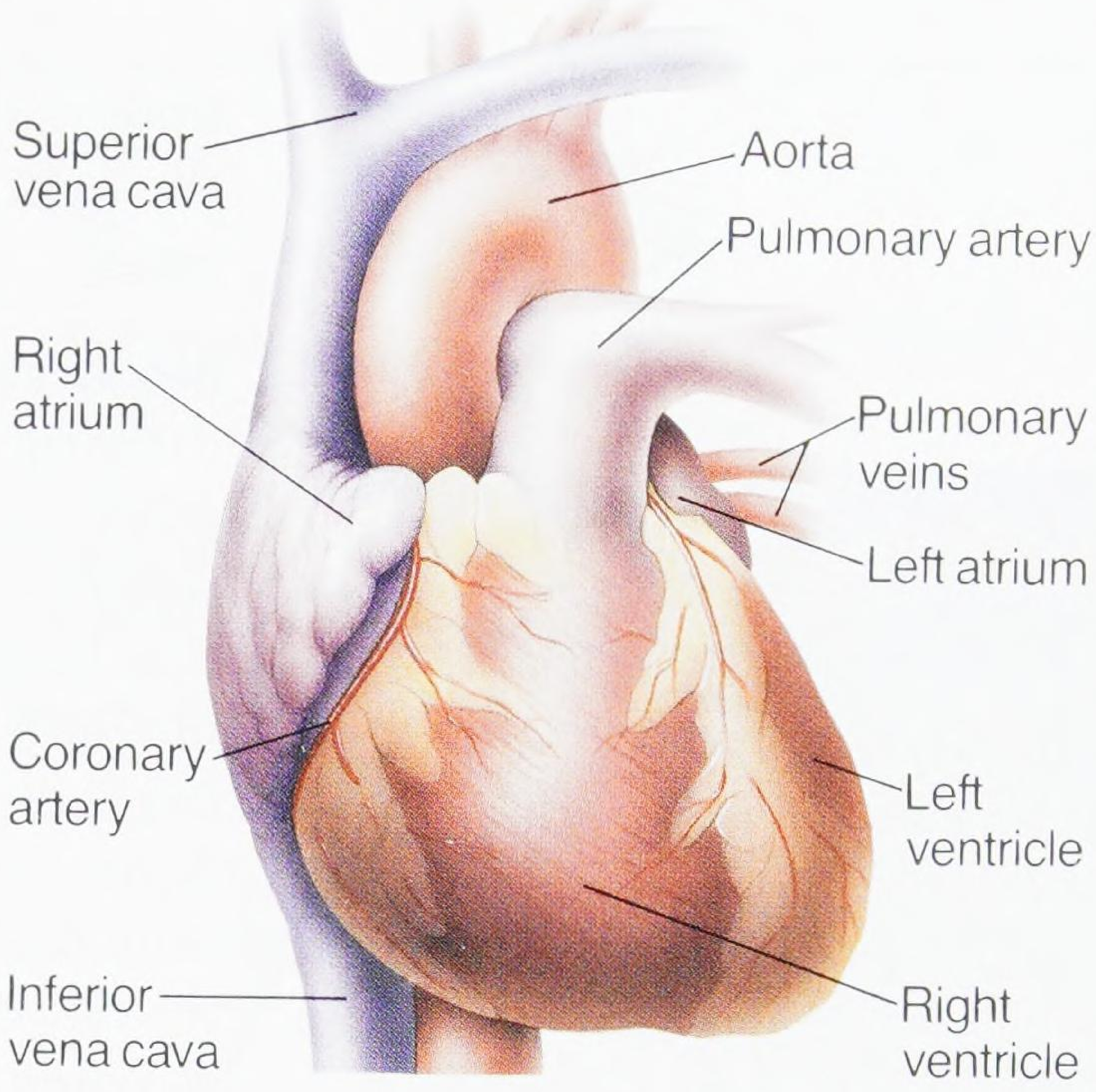

Superior vena cava
Aorta
Pulmonary artery
Right atrium
Pulmonary veins
Left atrium
Coronary artery
Left ventricle
Inferior vena cava
Right ventricle

Figure 20-2. In mammals, the heart is a two-pump organ. The right ventricle pumps oxygen-poor blood to the lungs, and the left ventricle pumps oxygen-rich blood to body tissues.

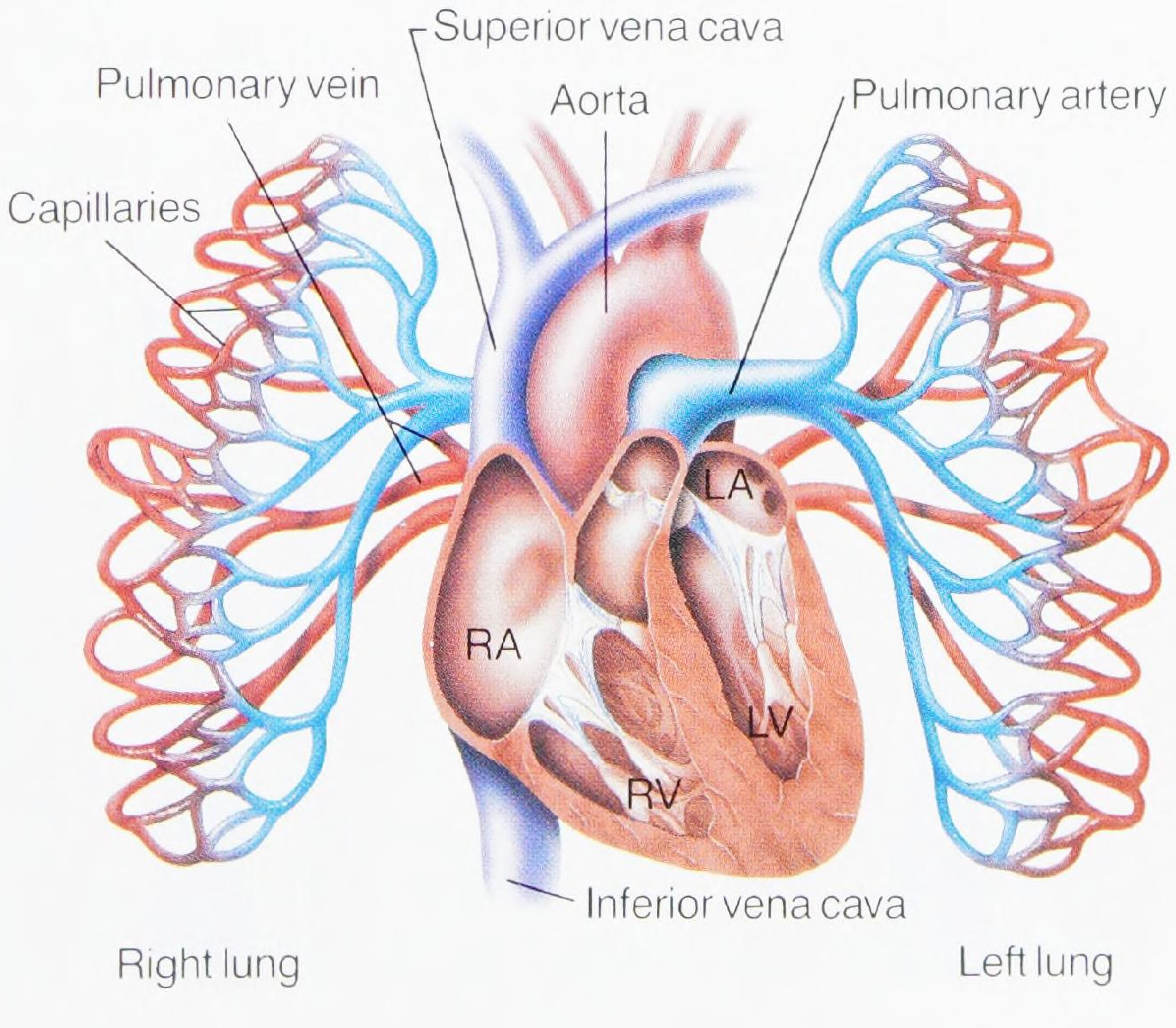

Superior vena cava
Pulmonary vein
Aorta
Pulmonary artery
Capillaries
LA
RA
LV
RV
Inferior vena cava
Right lung
Left lung

Figure 20-3. Pulmonary circulation moves blood between the heart and lungs.

body parts. Use Figure 20-3 to trace the pathway of blood through the heart, to the lungs, and back to the heart again.

Blood Vessels

Until the work of William Harvey was published in 1628, many people believed that blood moved back and forth in the body like an ocean tide. His work showed that blood circulates only in one direction and that it is moved by the pumping action of the heart. He found that blood flows from arteries to veins. But he couldn't figure out how blood got from arteries to veins. It wasn't until the invention of the microscope that capillaries, the tiniest vessels of the cardiovascular system, were seen.

When blood is pushed out of your heart, it begins a journey through your arteries, capillaries, and veins. **Arteries** are blood vessels that move blood *away* from your heart. Arteries have thick elastic walls that are lined with smooth muscle. Each ventricle of the heart is connected to an artery, so with each contraction blood is moved from the heart into arteries.

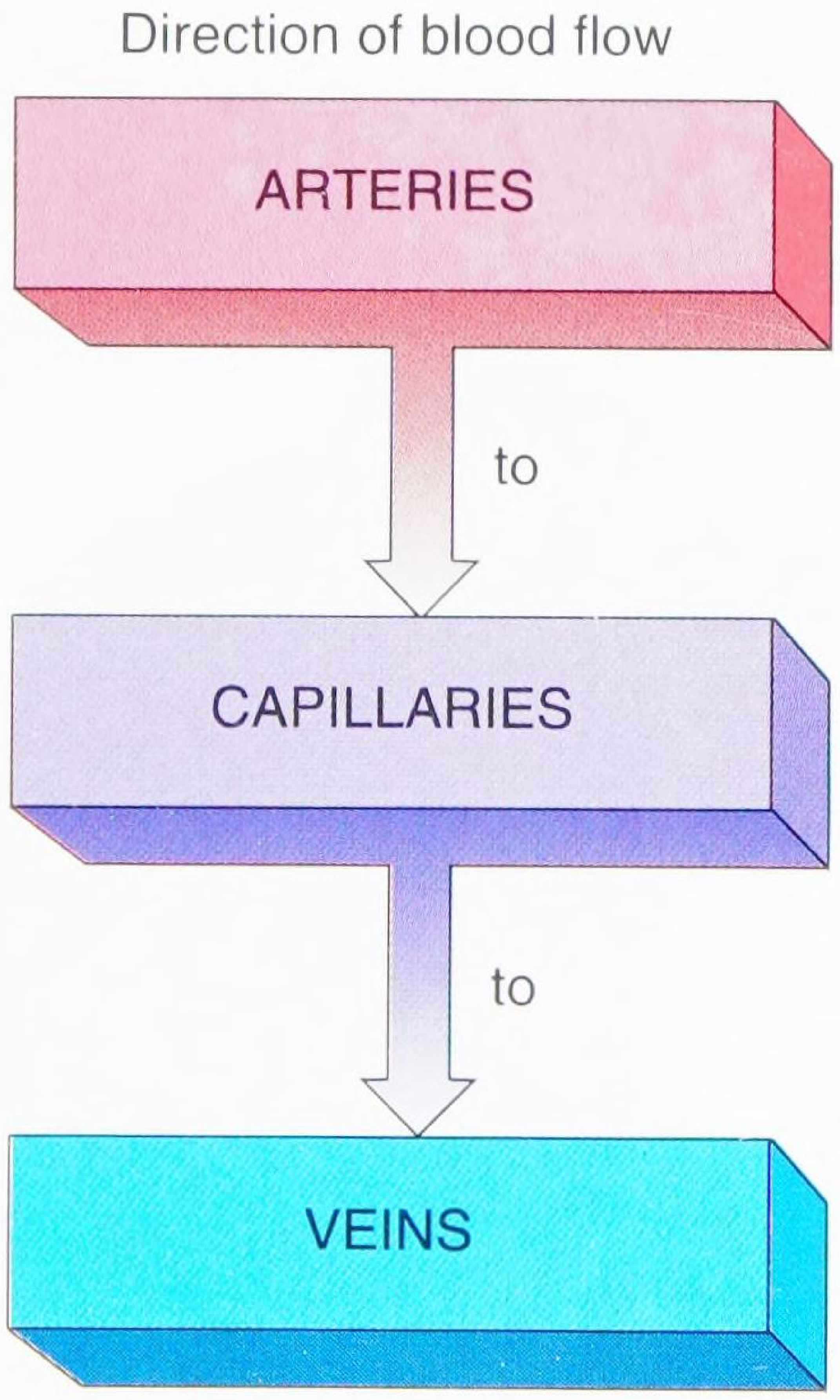
Veins are blood vessels that move blood *to* the heart. Veins have one-way valves to keep blood moving toward the heart. If there is a backward movement of the blood, the pressure of the blood closes the valves. The greatest number of valves are in veins in the legs. Why do you think this is so? Veins that are near skeletal muscles are squeezed when these muscles contract. This action also helps blood move toward the heart. Blood in veins carries waste materials from cells and is therefore low in oxygen.

Capillaries are microscopic blood vessels that connect arteries and veins. The walls of capillaries are only one

MINI-Lab

What are the parts of the heart?

Draw and label a diagram of the heart. Color the oxygen-rich parts red and the carbon-dioxide parts blue. *Interpret* the purpose served by the thick septum or wall of muscle between the left and right sides of the heart. How is the heart of a "blue baby" different?



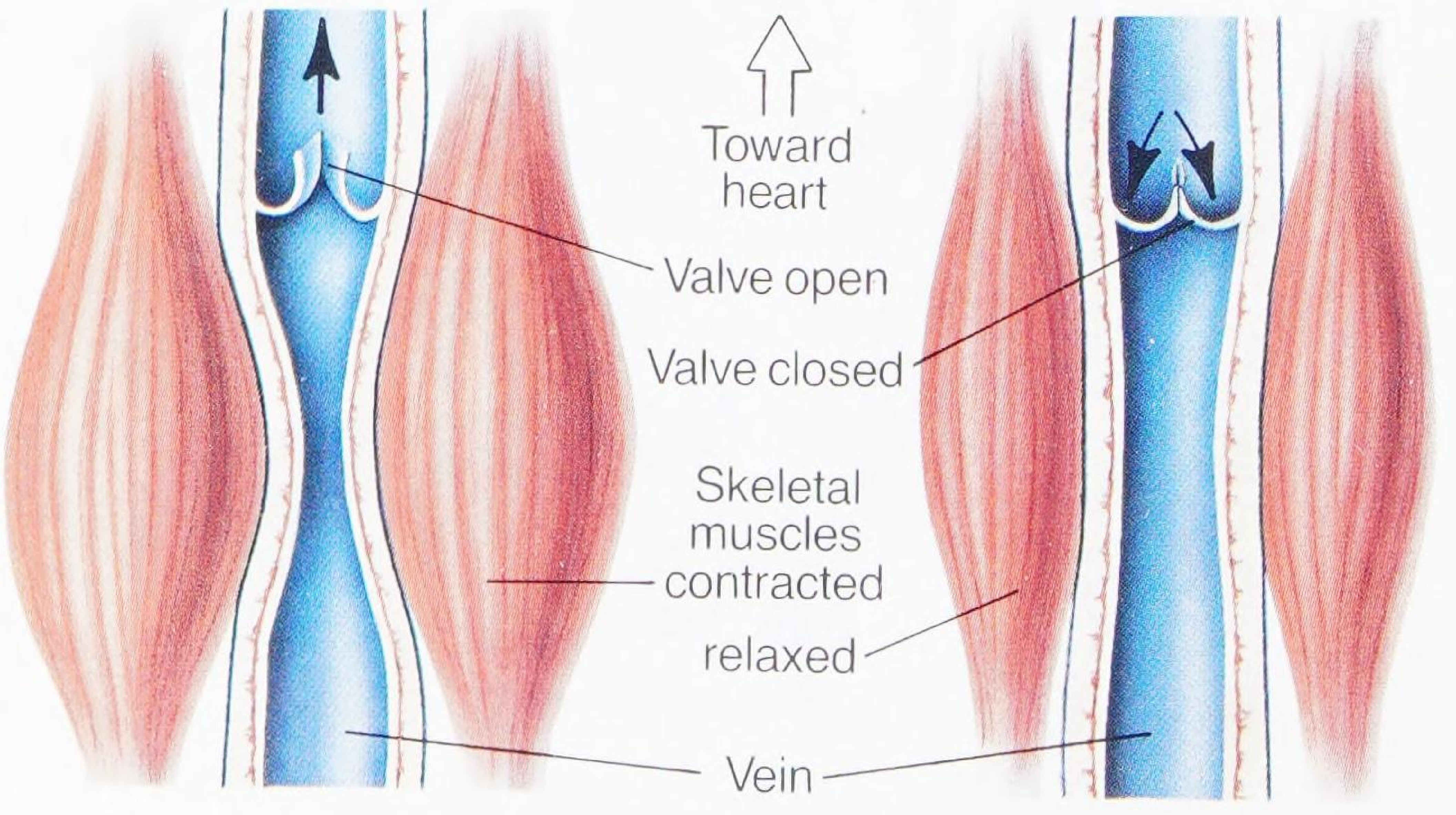


Figure 20-4. Blood flows from arteries to capillaries to veins. Valves in veins and muscles to the right help blood flow back toward the heart.

cell thick. Food and oxygen diffuse to body cells through the small capillary walls. Waste materials move from body cells into the capillaries to be carried back to the heart.

Systemic circulation moves blood to all body tissues except the lungs and heart. This is the longest of the three pathways. It carries oxygen-rich blood from the left ventricle through the aorta to arteries and capillaries in all the organs and tissues of the body. Nutrients and oxygen are exchanged for carbon dioxide and wastes. Blood returns to the heart in veins from the head and neck through the superior vena cava. Blood returns from your abdomen and the lower parts of your body through the inferior vena cava to the right atrium. Then, oxygen-poor blood is sent to the lungs.

Your heart has its own blood vessels that supply it with nutrients and oxygen and remove wastes. These blood vessels are the coronary arteries and veins. It is on these blood vessels that coronary by-pass surgery is performed. **Coronary circulation** is the flow of blood to the tissues of the heart.

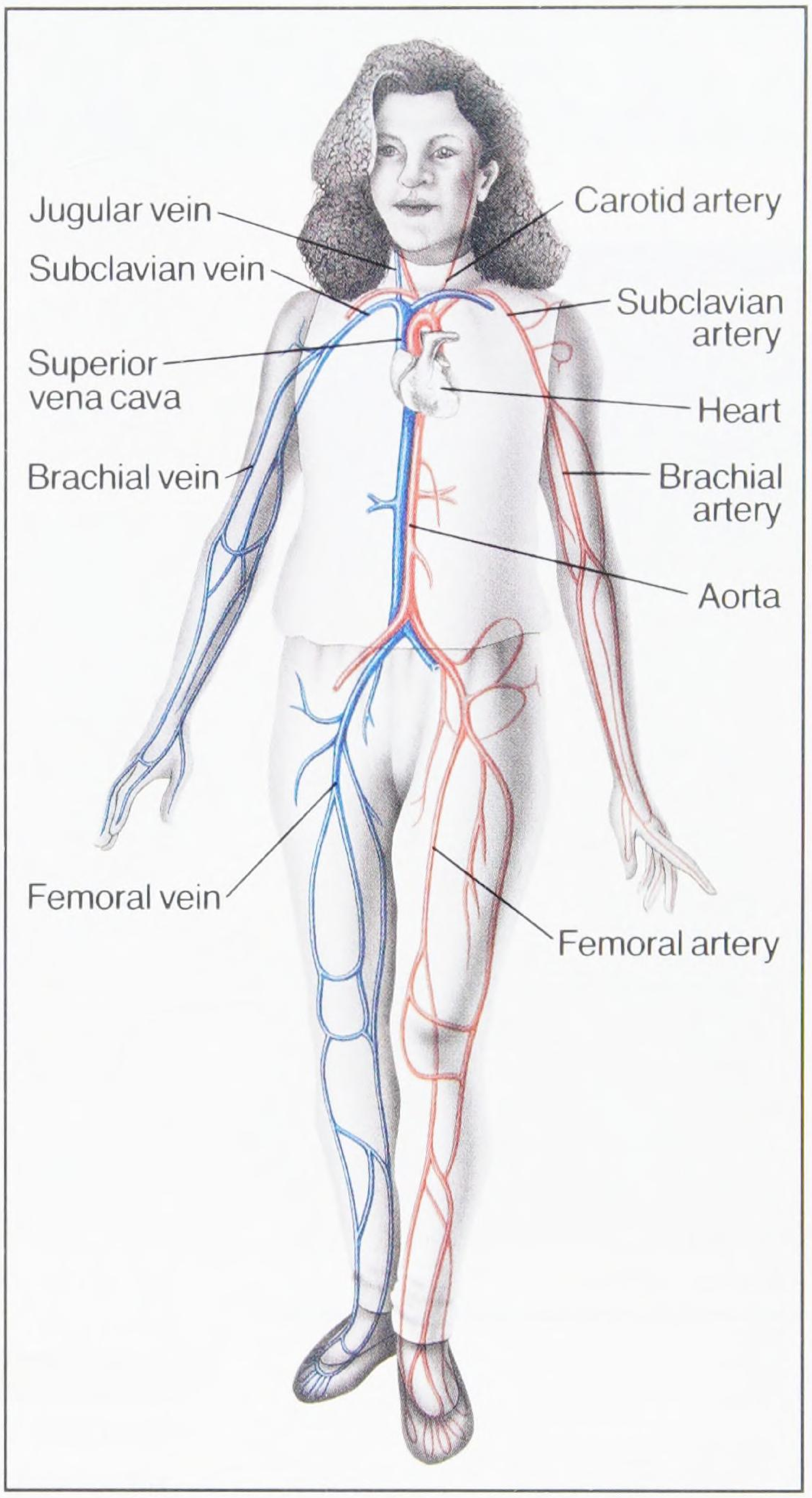


Figure 20-5. Systemic Circulation

Blood Pressure

When you pump up a bicycle tire, you can feel the pressure of the air on the walls of the tire. In the same way, when the heart pumps blood through the cardiovascular system, blood exerts a force called **blood pressure** on the walls of the vessels. This pressure is highest in arteries.

As the wave of pressure rises and falls in your arteries, it is felt throughout your body as a pulse. Normal pulse rates are between 65 and 80 beats per minute. There is less pressure in capillaries and even less in veins.

Blood pressure is measured in large arteries and is expressed by two numbers, such as 120 over 80. The first number is a measure of the pressure caused when the ventricles contract and blood is pushed out of the heart. Then blood pressure suddenly drops as the ventricles relax. The lower number is a measure of the pressure when the ventricles are filling up, just before they contract again.

Connect to...

Physics

According to a law of physics, when pressure is exerted on a fluid in a closed container, the pressure is transmitted through the liquid in all directions. Your circulatory system is like a closed container and each heart beat exerts pressure. Where do you think that pressure is transmitted?

Diseases and Disorders of the Heart

Any disease or disorder that affects the cardiovascular system can be serious to a person's health. The term *heart disease* is often used to describe any of the health problems that affect the heart. Heart disease is the major cause of death in the United States.

One leading cause of heart disease is **atherosclerosis** (ath uh roh skluh ROH sus), a condition of fatty deposits on arterial walls. Eating too many foods that contain cholesterol can cause these deposits. The fat can build up and form a hard mass that clogs the inside of the vessel. As a result, less blood flows through the artery. If the artery is clogged completely, blood is not able to flow through. When this occurs in a coronary artery, it can cause a heart attack. If an artery in the brain is clogged, a stroke can occur.

Another common disorder of the cardiovascular system is high blood pressure, or **hypertension** (hi pur TEN chun). One cause of hypertension is the condition described above. A clogged artery can cause the pressure within the vessel to increase. This can cause the walls to lose their ability to contract. There also is extra strain on the heart to work harder to keep blood flowing. Being overweight as well as eating foods with too much salt and fat may contribute to hypertension. Smoking and stress also can increase blood pressure.

Your cardiovascular system efficiently provides your body cells with nutrients and oxygen and removes cell wastes. A well-functioning cardiovascular system is important for good health. You can promote a healthy heart! Choose to eat a healthful diet and exercise regularly.

MINI-Lab

How does a stethoscope work?
Listen to your heart through a stethoscope. What is causing the sounds you hear? *Describe* the two sounds.

In Your JOURNAL

What is a bypass operation? Write to the local office of the American Heart Association and find out about bypass operations. Write a report **in your Journal** about how this operation aids victims of atherosclerosis.

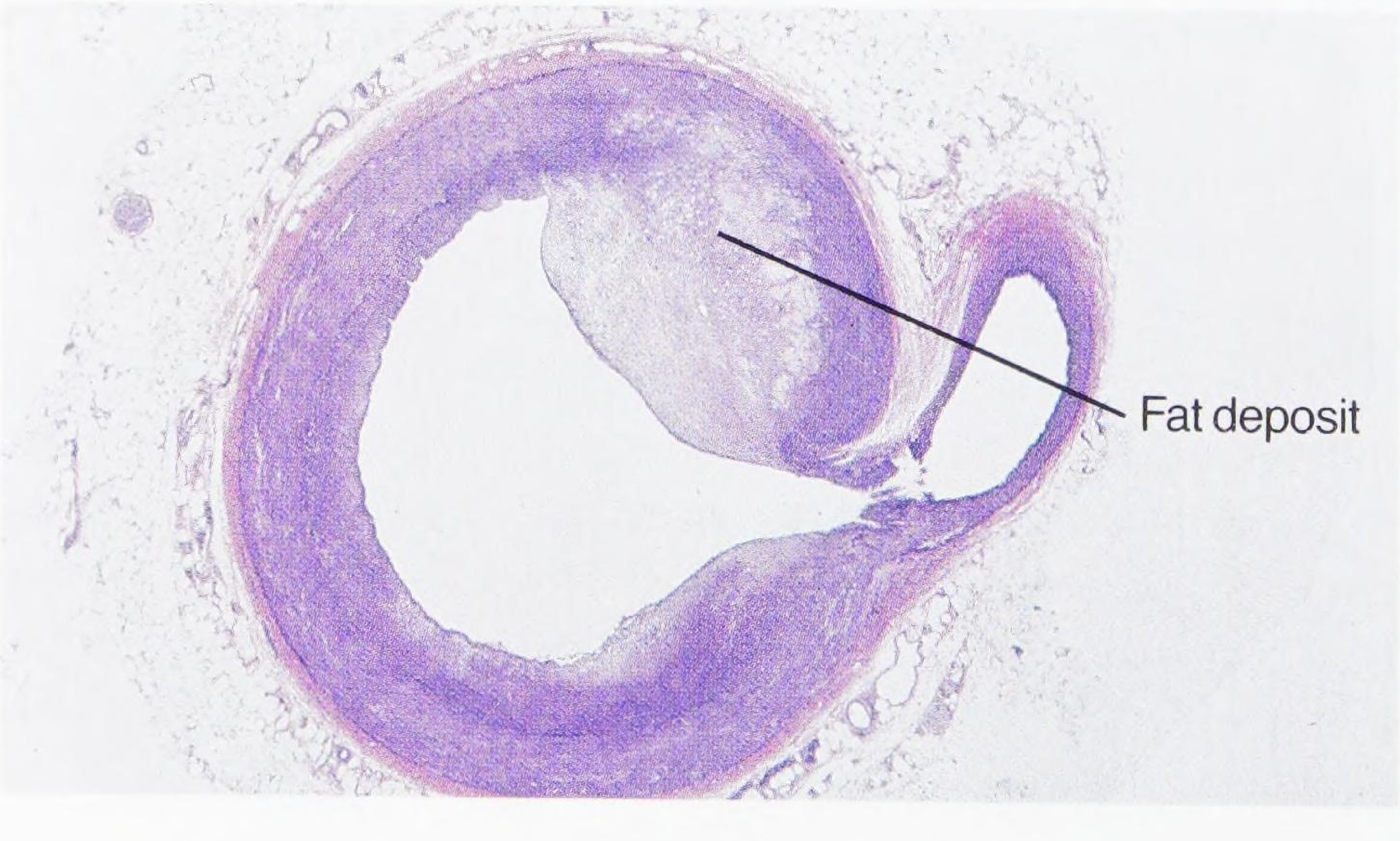


Figure 20-6. Atherosclerosis interferes with blood flow by blocking blood vessels with fatty substances.

TECHNOLOGY

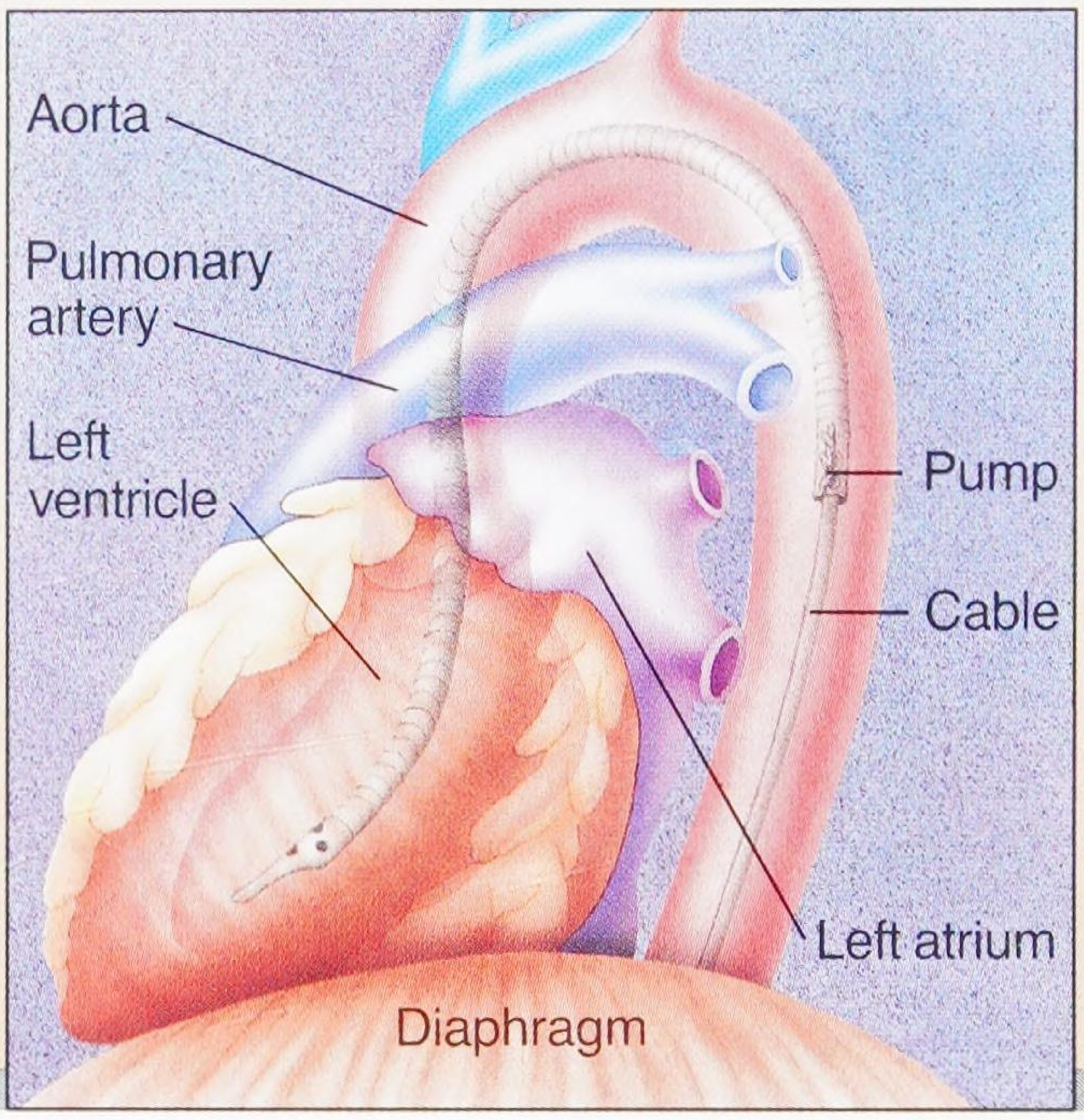
An Assist for the Heart

Some patients need temporary help until a damaged or transplanted heart is able to function properly. Miniature heart pumps, like the Hemopump, may be the answer.

The Hemopump is the size of the eraser of a number 2 pencil. When a transplanted heart shows signs of being rejected, the Hemopump can take over, pumping blood for several days until antirejection drugs allow the patient's new heart to function.

The Hemopump is inserted into an artery in the upper part of the leg. From here it is carefully pushed up through the blood vessels into the left ventricle. A tiny blade, making 25 000 revolutions per minute, draws the blood through the tube and spills it into the aorta. The pump is connected to a motor outside the patient's body by a thin cable. The operation to insert the pump takes 20 minutes.

Think Critically: How could the Hemopump be used to help victims of heart attack?



SECTION REVIEW

1. Compare and contrast the three types of blood vessels.
2. Explain the pathway of blood through the four chambers of the heart.
3. Contrast pulmonary and systemic circulations.
4. **Apply:** Your heart, like any muscle, needs exercise. What exercises should you do to give your heart a workout?
5. **Connect to Chemistry:** What respiration waste product builds up in blood and cells when the heart is unable to pump blood efficiently?

Skill Builder

Concept Mapping

Make an events chain concept map to show pulmonary circulation beginning at the right atrium and ending at the aorta. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

ACTIVITY 20-1

Taking Blood Pressure

Problem: *How can you measure arterial pressure?*

Materials

- sphygmomanometer
- stethoscope
- table
- chairs (2)
- alcohol
- cottonballs

Procedure

1. Your partner should sit down on a chair with his or her arm on the table. One hand should face up as in the photo.
2. Sit and face your partner. Place the blood pressure cuff on your partner's arm above the elbow. Align the arrows on the cuff. Close the cuff snugly.
3. Close the valve on the pump. Place the ear pieces of the stethoscope in your ears. Place the round stethoscope head on your partner's brachial artery as shown in photograph. Squeeze the pump until the needle reaches 160 on the gauge. No blood will flow through this constricted area.
4. *Slowly* open the valve of the pump. *Do not open the valve quickly. Observe* the gauge. The needle will drop at a constant rate. Watch for the number on the gauge when you first hear a beat. This is the top, or systolic, number.
5. Keep listening for a heartbeat. *Observe* the needle on the gauge. Note the number on the gauge when you no longer hear a beat. This is the bottom, or diastolic, number. At this point, blood pressure has dropped; blood flow has returned to normal.
6. Take the cuff off your partner's arm. Record your partner's blood pressure. Clean ear pieces with alcohol. Trade places with your partner. **CAUTION:** *Do not do this activity on the same person more than one time per class period.*
7. *Make* and fill in *a table* like the one shown.

Analyze

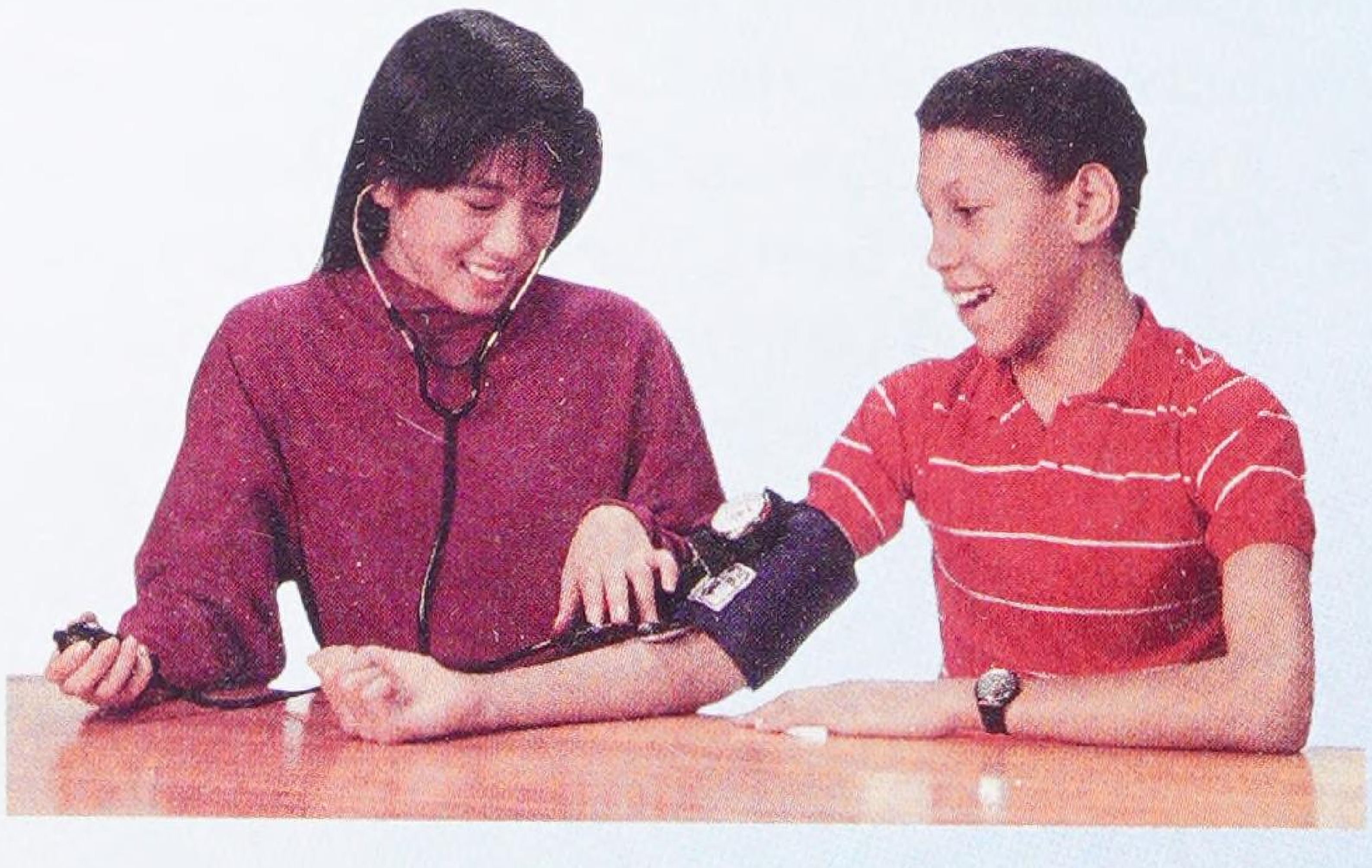
1. Describe what happened in your brachial artery during this activity.
2. As you listened to your partner's blood pressure, what did you notice about the needle on the gauge when you first heard the heartbeat rate and later when it stopped?

Conclude and Apply

3. How was your blood pressure different from your partner's?
4. What can you *infer* about a person who has low blood pressure?

Data and Observations

Blood Pressure	Example	Yours	Partner's
Systolic	120		
Diastolic	80		



Blood

20-2

Objectives

- **Describe the characteristics and functions of the parts of blood.**
- **Explain the importance of checking blood types before a transfusion is given.**
- **Describe a disease and a disorder of blood.**

New Science Words

plasma
hemoglobin
platelets

Functions of Blood

Blood makes up about eight percent of your body's total mass. If you weigh 45 kg, you have about 3.6 kg of blood moving through your body. The amount of blood you have in your body would fill five one-liter bottles. If this volume falls, the body is sent into shock because blood pressure falls rapidly.

What does blood consist of?

Blood is a tissue consisting of cells, cell fragments, and liquid. Blood has many important functions. It plays a part in every major activity of your body. First, blood carries oxygen from your lungs to all body cells. It also removes carbon dioxide from your body cells and carries it to the lungs to be exhaled. Second, it carries waste products of cell activity to your kidneys to be removed. Third, blood transports nutrients from the digestive system to body cells. Fourth, materials in blood fight infections and help heal wounds. Anything that disrupts or changes any of these functions affects all the tissues of the body.

Parts of Blood

If you've ever taken a ride in a water slide at an amusement park, you have some idea of the twisting and turning travels of a blood cell inside a blood vessel. Surrounded by water, you travel rapidly through a narrow watery passageway, much like a red blood cell moves in the plasma of blood.

O
AB
A
Rh POSITIVE
VOLUNTEER DONOR

Figure 20-7. Donated blood is measured in units. The units pictured show how much blood is in your body.

In Your JOURNAL

CPR is a life-saving technique everyone should know. **In your Journal,** write what the letters stand for. Analyze the parts of the words to find out what they mean. Find out where you can learn CPR.

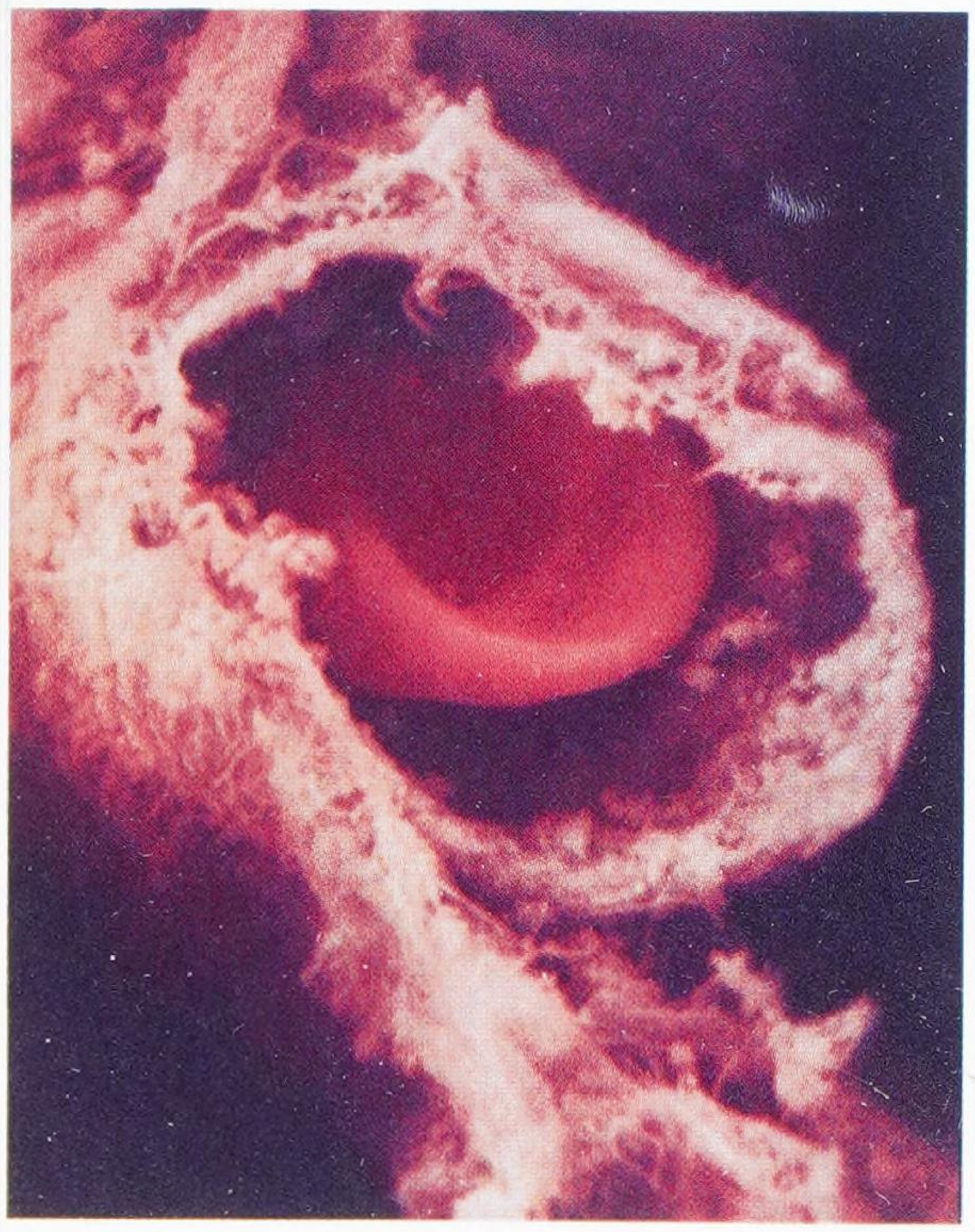
If you examine blood closely, you would see that is it not just a red-colored liquid. Blood is a tissue made of red and white blood cells, platelets, and plasma. **Plasma** is the liquid part of blood and consists mostly of water. Plasma makes up more than half the volume of blood. Nutrients, minerals, and oxygen are dissolved in plasma.

A cubic millimeter of blood has more than five million red blood cells. These disk-shaped blood cells contain **hemoglobin,** a chemical that can carry oxygen and carbon dioxide. Hemoglobin carries oxygen from your lungs to body cells. Red blood cells also carry carbon dioxide from body cells to your lungs. Red blood cells have a life span of about 120 days. They are formed in the marrow of long bones at a rate of two to three million per second and contain no nuclei. About an equal number of old ones wear out and are destroyed in the same time period.

In contrast to red blood cells, there are only about five to ten thousand white blood cells in a cubic millimeter of blood. White blood cells fight bacteria, viruses, and other foreign substances that constantly try to invade your body. Your body reacts to infection by increasing its number of white blood cells. White blood cells slip between the cells of capillary walls and out around the tissues that have been invaded. Here, they ingest foreign substances and dead cells. The life span of a white blood cell is about 30 days.

Platelets are irregularly shaped cell fragments that help clot blood. A cubic millimeter of blood may contain as many as 400 thousand platelets. Platelets have a life span of five to nine days. Table 20-1 summarizes the solid parts of blood and their functions.

Figure 20-8. A cut vessel below shows an escaping red blood cell. Blood as shown on the right, contains disc-shaped red blood cells, a white cell (with a wrinkled appearance), and platelets, small irregularly shaped fragments.



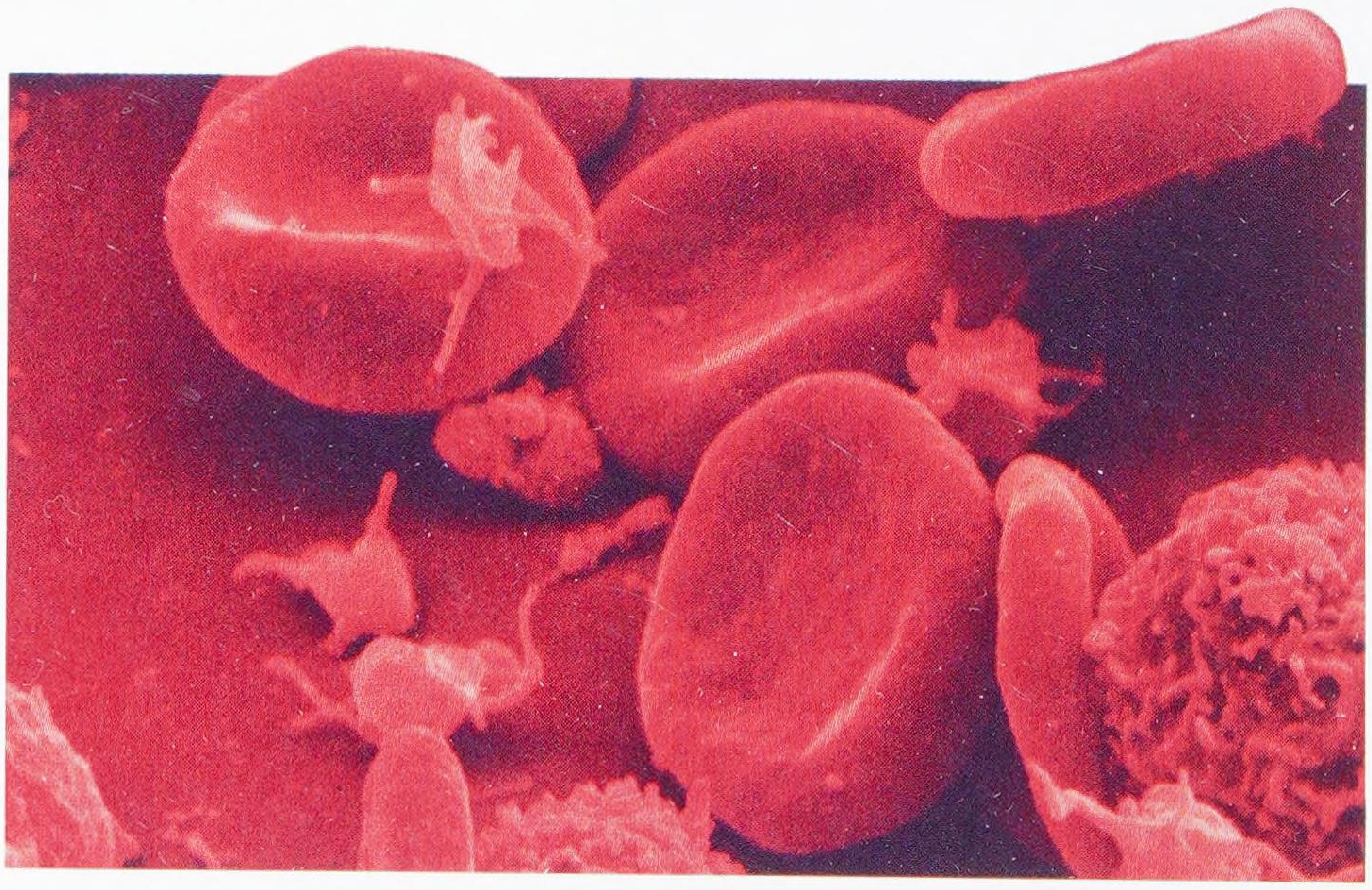


Table 20-1

TYPES OF BLOOD CELLS			
Name	**Nucleus**	**Function**	**Where Formed**
Red blood cells	no	carry oxygen and carbon dioxide	red bone marrow
White blood cells	yes	destroy bacteria, foreign substances	red bone marrow, some move to lymph tissue to produce more white blood cells
Platelets	no	help form blood clots	red bone marrow (fragments of another type of blood cell)

Connect to... Chemistry

When you have a cut, substances released by broken platelets start chemical reactions that cause fibers to form. These fibers trap cells and a clot forms. Find out about the role of calcium and vitamin K in blood clotting.

Blood Clotting

It would be serious if you got a paper cut that would not stop bleeding. Platelets in your blood help prevent loss of blood by making a blood clot. A blood clot is somewhat like a bandage. When you cut yourself, a series of chemical reactions cause threadlike fibers called fibrin to form a sticky net that traps escaping blood cells and plasma. This forms a clot and helps prevent further loss of blood. Blood clots are important for homeostasis. Figure 20-9 shows blood clotting after a cut.

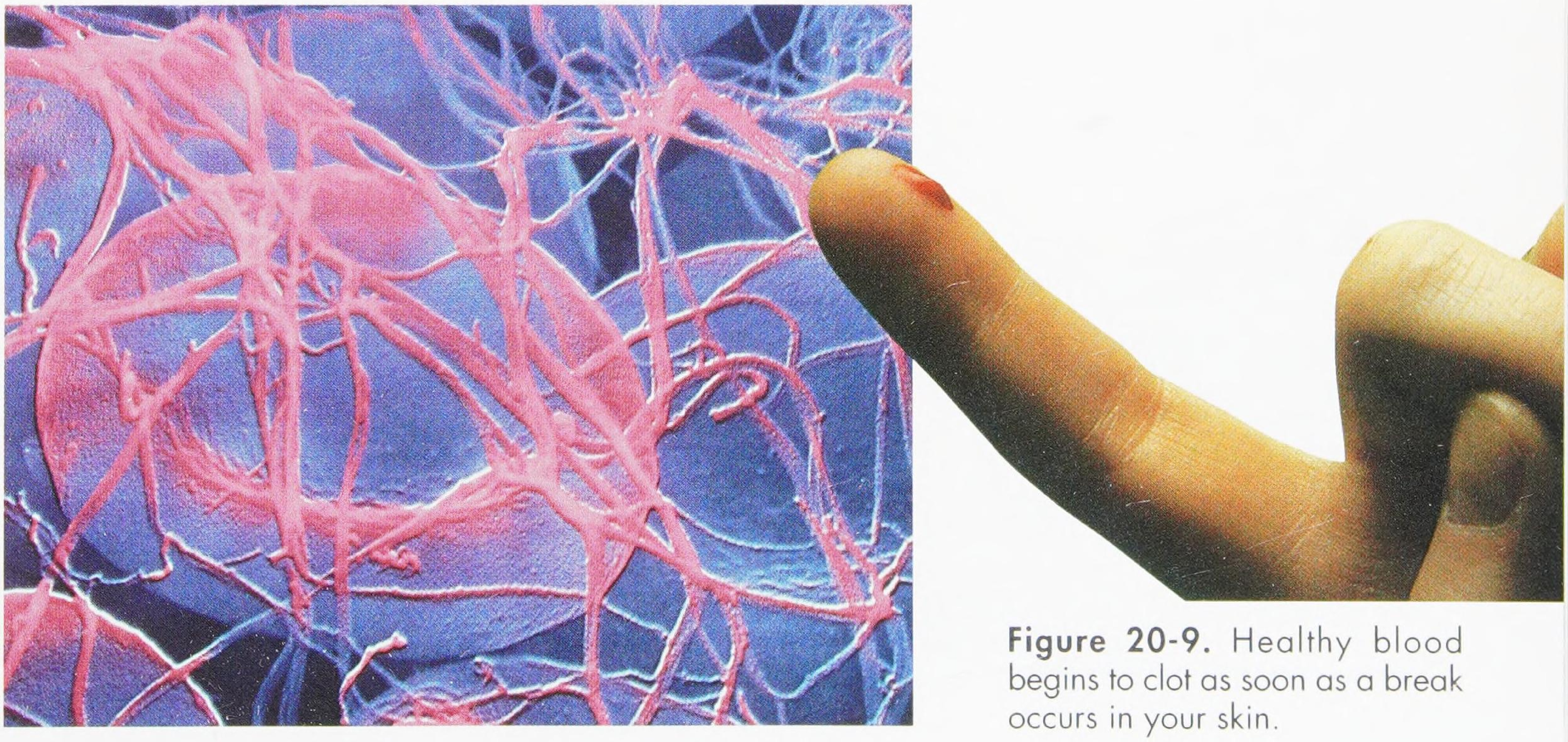
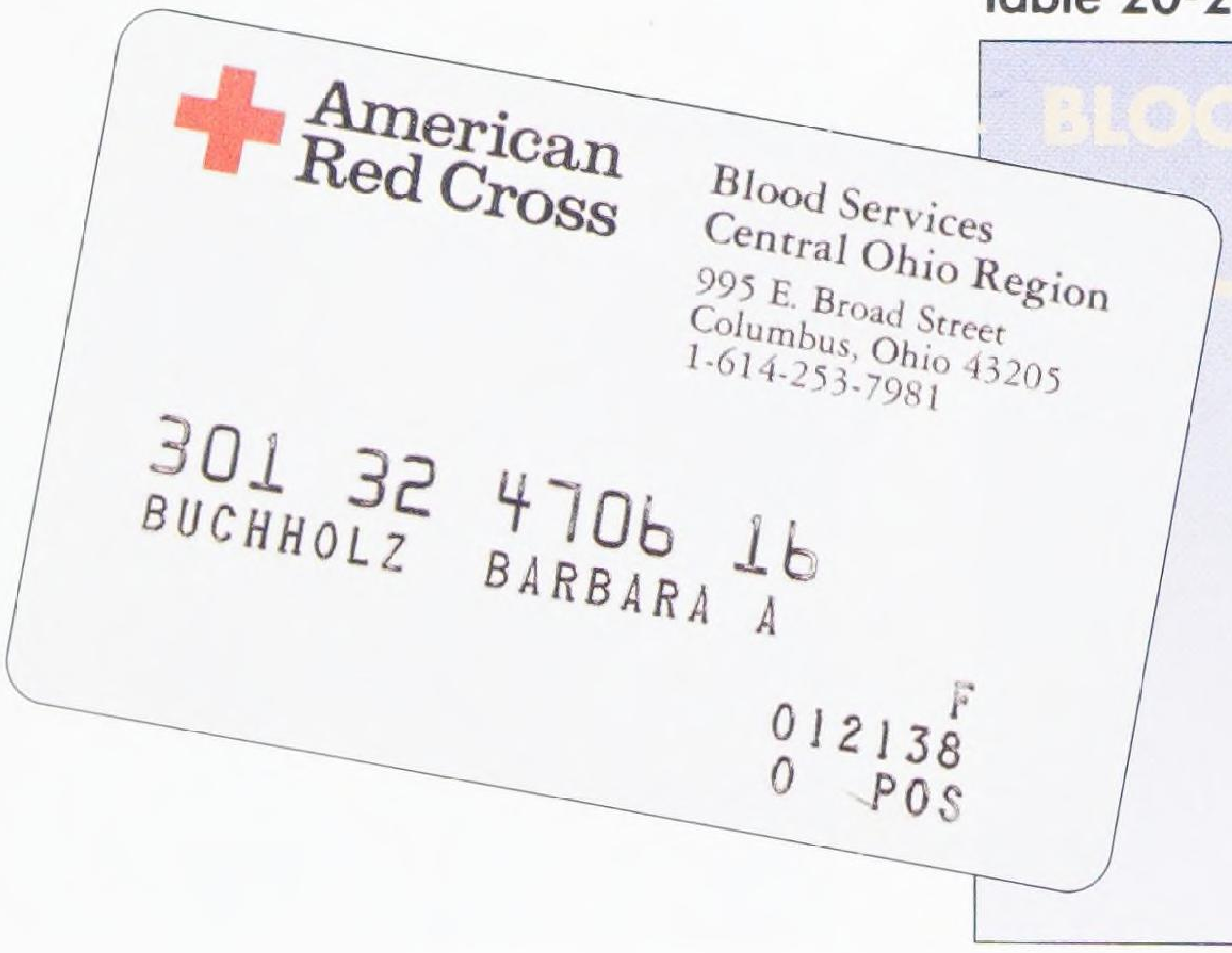


Figure 20-9. Healthy blood begins to clot as soon as a break occurs in your skin.

Blood Types

Sometimes, after an accident or during surgery, a person loses a lot of blood. This person may receive blood from another person through a blood transfusion. During a blood transfusion, a person receives blood or parts of blood. In the past, transfusions could cause red blood cells to clump together. Clots would form in blood vessels and result in death. Then, in the early 1900s, Dr. Karl Landsteiner, an Austrian-American scientist, discovered that there are four different types of blood. He called the four types A, B, AB, and O. Landsteiner found that each type has a chemical identification tag called an antigen on its red blood cells. Type A blood has A antigens. Type B has B antigens. Type AB has both A and B antigens on each blood cell. Type O has no A or B antigens.

Each type also has specific antibodies in the plasma of that blood. Antibodies are proteins that destroy or neutralize foreign substances, such as pathogens, in your body.The antibodies prevent certain different blood types from mixing. Type A blood has antibodies against type B. If you mix type A blood with type B blood, type A red blood cells react to type B blood as if it were a foreign substance. The antibodies in type A respond by clumping the type B blood. Type B blood has antibodies against type A. Type AB has no antibodies, so it can receive blood from A, B, and AB. Type O has both A and B antibodies. Table 20-2 lists the four blood types, what they can receive, and what types they can donate to.



American Red Cross

Blood Services
Central Ohio Region
995 E. Broad Street
Columbus, Ohio 43205
1-614-253-7981

301 32 4706 16
BUCHHOLZ BARBARA A
F
012138
0 POS

Table 20-2

BLOOD TRANSFUSION POSSIBILITIES

Type	Can receive	Can donate to
A	O, A	A, AB
B	O, B	B, AB
AB	all	AB
O	O	all

PROBLEM SOLVING

The Blood Type Mystery

Detective Johnson was on to something. He had been assigned to a confusing robbery case. He had received conflicting testimony from the people involved. Now he had the last piece of evidence he needed to solve the crime.

A person had come home to find someone he knew robbing his apartment. The victim struggled with the robber. He broke a vase over the robber's head. The victim later identified the robber in a police lineup, but the robber said he had an alibi.

While investigating, Detective Johnson found blood on the vase and carpet. He sent the blood to a lab to be analyzed. The blood of the victim and robber also were analyzed, even though the robber offered proof that he had just received a blood transfusion with type O blood.

When Detective Johnson received the blood analysis report, the blood on the vase and carpet was found to be type A. The victim's blood type was B. The robber's blood type was A. The robber was found guilty. The case was solved.

Think Critically: Explain what the robber didn't know about the blood he received.

If you have already studied the chapter on genetics in this textbook, then you know that blood type is inherited. You cannot change your blood type.

The Rh factor is another inherited substance in blood. If present, the person has Rh-positive (Rh+) blood. If it is not present, the person is said to be Rh-negative (Rh−). An Rh− person receiving blood from an Rh+ person will produce antibodies against the Rh+ factor.

A problem also occurs when an Rh− mother carries an Rh+ baby. Close to the time when the baby is about to be born, antibodies from the mother can cross the placenta and destroy the baby's red blood cells. If this happens, the baby can receive a blood transfusion before or right after birth. At 28 weeks and immediately after the birth, the mother can receive an injection that destroys any Rh+ antibodies she has made. Thanks to the work of Dr. Landsteiner, blood groups and Rh factor now are checked before transfusions and during pregnancies.

Did You Know?

Rh, or Rhesus, factor was first discovered in the rhesus monkey in 1940. From 85 to 90 percent of the people in the United States have this antigen, meaning that they are Rh-positive.

Diseases and Disorders of Blood

Blood, like any other tissue in your body, is subject to illness. Because blood circulates to all parts of the body and performs so many vital functions, any illness related to blood or circulation is cause for concern. Anemia is a disorder in which there are too few red blood cells, or too little hemoglobin in the red blood cells. Because of this, body tissues do not receive enough oxygen. They are unable to carry on their usual activities. Sometimes the loss of great amounts of blood or improper diet will cause anemia. Anemia can also result from the effects of a disease or side effects of treatment for a disease.

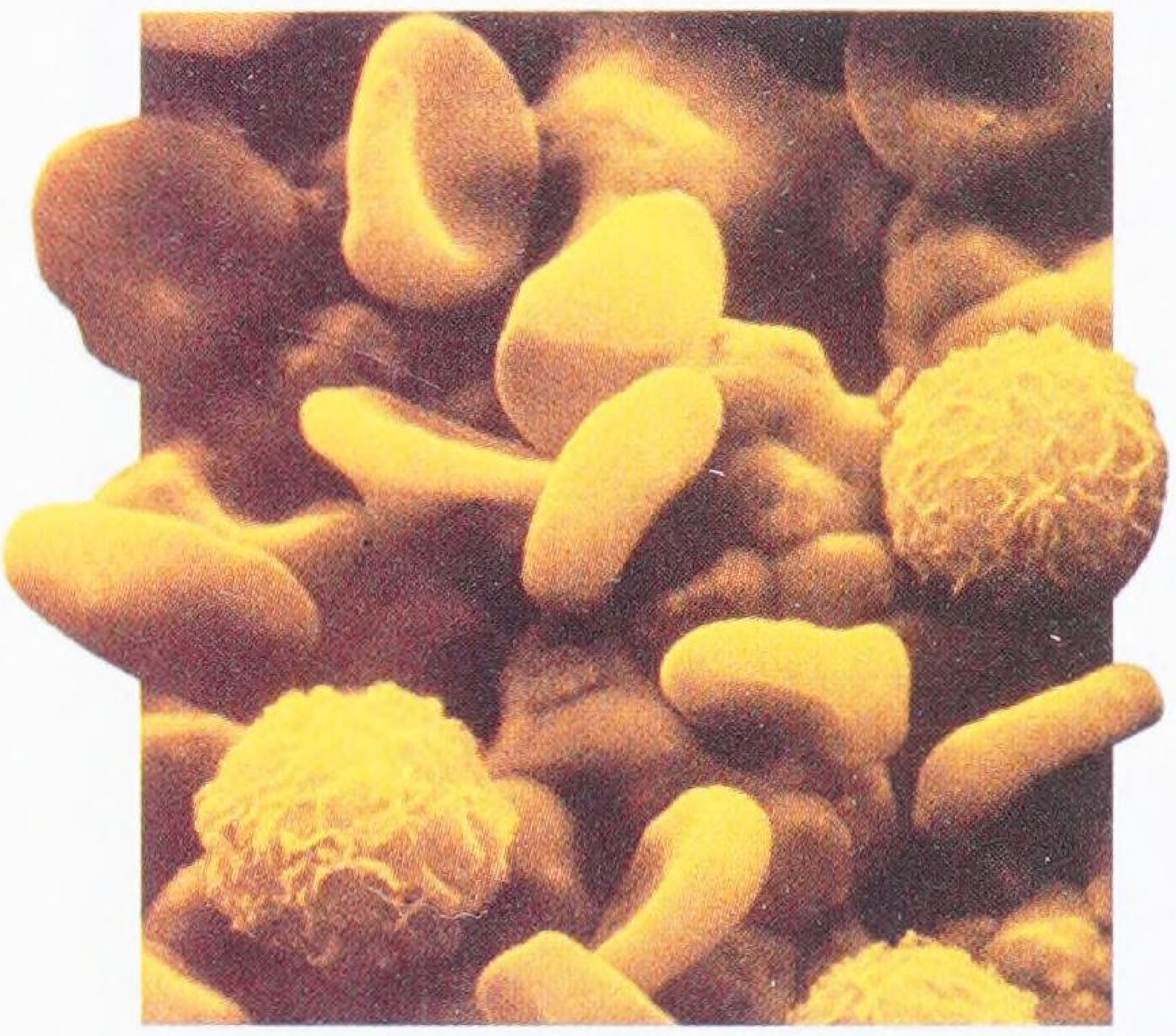


Figure 20-10. A sample of blood from a person with leukemia shows red blood cells and immature white blood cells.

Leukemia is a disease in which one or more types of white blood cells are produced in increased numbers. However, these cells are immature and do not effectively fight infections. Blood transfusions and bone marrow transplants are used to treat this disease, but they are not always successful.

Blood has many functions. It transports oxygen and nutrients to body cells. Blood takes wastes from these cells to organs for removal. Cells in blood help fight infection and heal wounds. You can understand why blood is sometimes called the tissue of life.

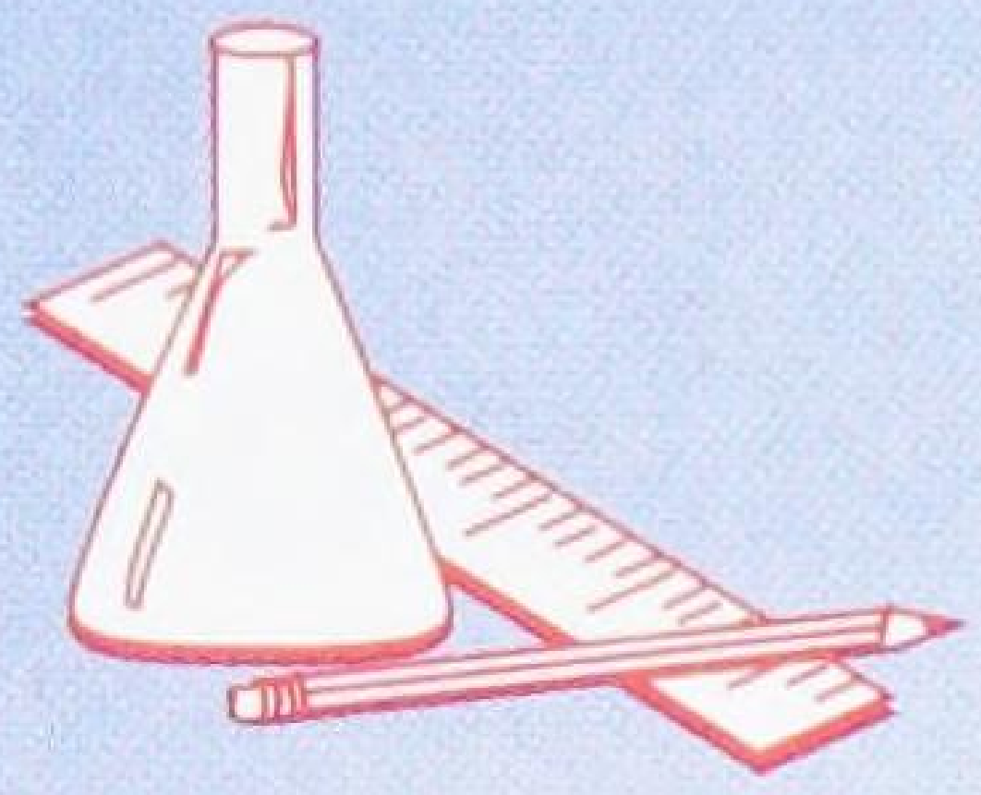
SECTION REVIEW

1. What are the four functions of blood in the body?
2. Compare blood cells, plasma, and platelets.
3. Why is blood type checked before a transfusion?
4. Describe a disease and a disorder of blood.
5. **Apply:** Think about the main job of your red blood cells. If red blood cells couldn't pick up carbon dioxide and wastes from your cells, what would be the condition of your tissues?
6. **Connect to Physics:** In sickle cell anemia abnormal hemoglobin causes some red blood cells to have a sickle shape. How can these odd shaped cells cause problems in the body?

Skill Builder

Making and Using Tables

Look at the data in Table 20-2 on page 474 about blood group interactions. To which group(s) can type AB donate blood? If you need help, refer to Making and Using Tables in the **Skill Handbook** on page 690.



ACTIVITY 20-2

Comparing Blood Cells

Problem: *How do human blood cells compare with those of other vertebrates?*

Materials

- prepared slides of human blood and blood of two other vertebrates (fish, frog, reptile, bird)
- microscope

Procedure

1. Under low power, *observe* the prepared slide of human blood. Locate the red blood cells.
2. Examine the red blood cells under high power.
3. In a table like the one shown, draw, count, and describe the red blood cells.
4. Move the slide to another position. Find one or two white blood cells. They will be blue or purple due to the stain.
5. Draw, count, and describe the white cells in the space provided in the table.
6. Still using high power, examine the slide for very small fragments that appear blue. These are platelets.
7. Draw, count, and describe the platelets in the table.
8. Follow Steps 1 to 7 for each of the two other slides of vertebrate blood.

Analyze

1. Which type of blood cells are present in the greatest number?
2. How do the red blood cells of the other vertebrates *compare* to the human cells?
3. How are the white blood cells alike or different among vertebrates?
4. Are the platelets all alike?

Conclude and Apply

5. Does each vertebrate studied have all three cell types?
6. What might you *infer* about the ability of the different red blood cells to carry oxygen?
7. Describe the function of each of the three types of blood cells.
8. Describe how technology might design a new type of red blood cell to carry more oxygen.

Data and Observations

Vertebrate type	Blood cell type	Description	Number in field	Drawing
Human	Red			
	White			
	Platelets			
Bird	Red			
	White			
	Platelets			
Frog	Red			
	White			
	Platelets			

SCIENCE & SOCIETY

20-3 Autologous Blood Transfusions

New Science Words

homologous blood transfer
autologous blood transfer

Objectives

- Explain the advantages of an autologous blood transfusion.
- Name one problem with saving one's own blood.

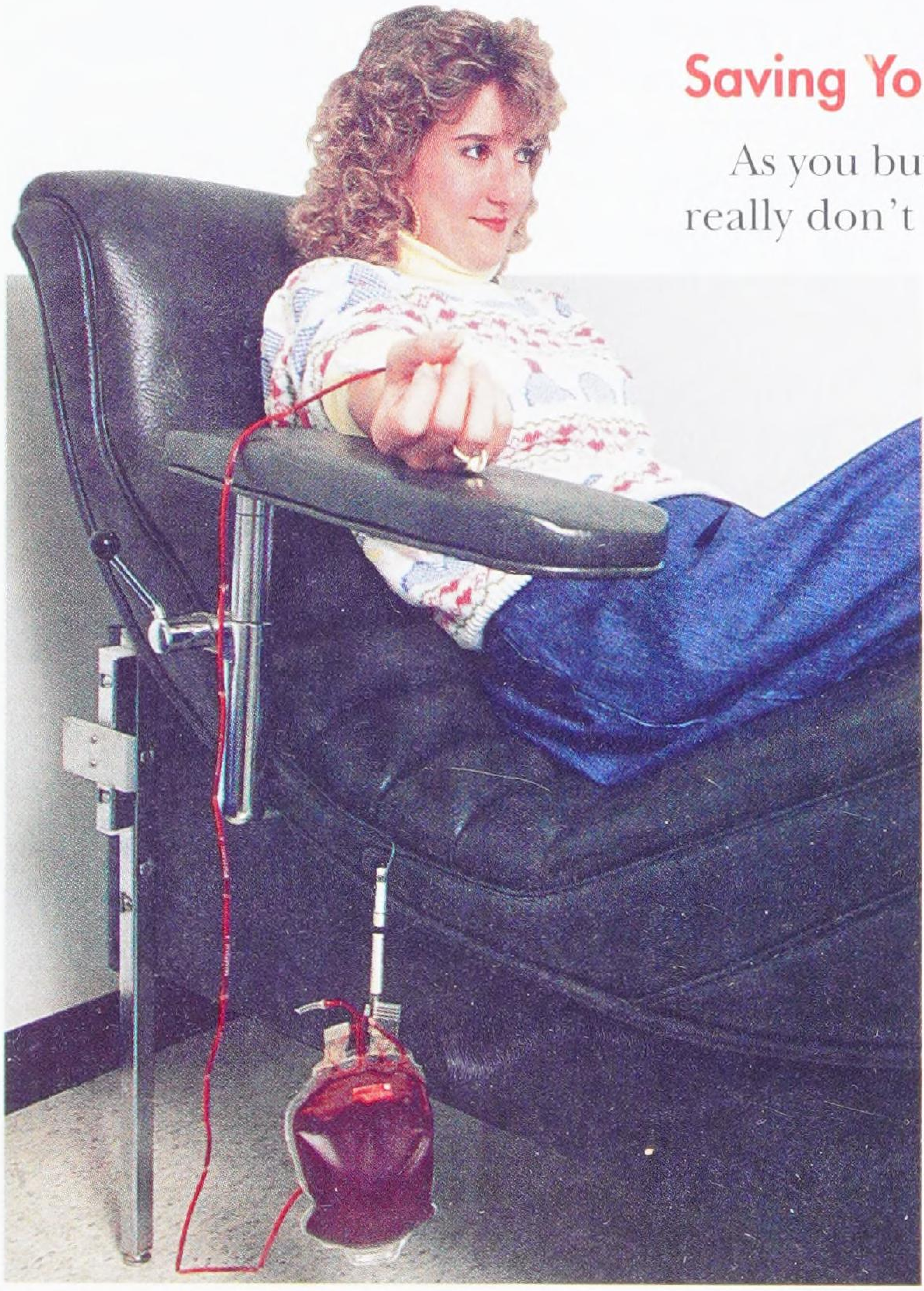


Figure 20-11. Autologous blood transfer involves giving and storing your own blood for your own future use.

Saving Your Own Blood

As you buy a snack, new T-shirt, or magazine (that you really don't need), you might feel a bit guilty about not saving that money away somewhere so it will be safe until you really need it. Today, doctors are suggesting that money isn't the only thing that people should be putting in the bank. Have you ever read about someone storing his or her own blood just in case it is needed?

Because new blood cells are constantly being produced in the body, lost blood is replaced quickly in a healthy person. You probably know that the Red Cross Blood Mobile collects units of blood from individuals willing to donate to others who might need blood. A **homologous blood transfer** is blood taken from one person and given to another. Some people store their own blood if they are anticipating surgery. **Autologous** (aw TAHL uh gus) **blood transfer** is the use of one's own blood for transfusion. This blood is collected prior to surgery.

Unfortunately, there are several drawbacks to this technology. The biggest problem lies in the expense of storing blood. Doctors estimate that it costs about $200 per year to safely store blood. In addition, the patient may be hundreds or thousands of miles away from his or her blood bank when the blood is needed.

However, in response to people who are interested in this procedure, doctors at Northwestern Memorial

Hospital in Chicago have developed two forms of autologous blood transfusion. Blood lost during surgery is collected with suction devices. This blood may be put back into the patient's body after it has been cleansed. Lost blood also can be collected with sponges and squeezed out into a bowl of saline, a type of salt solution. Within 15 minutes, it is processed and put back into the patient's circulation. By using both methods, doctors believe that they can recover up to 90 percent of blood that would otherwise be lost.

Still, in some situations, it is very difficult to collect blood from a patient if much of it is lost before medical help is available. To solve this problem, doctors are working on ways to develop artificial hemoglobin that would temporarily transport oxygen and carbon dioxide throughout the body. Another idea being researched is the reproduction of a hormone that causes the body to produce blood cells much more quickly than it normally does. This would allow the body to replace much of its own blood rather than having to receive new blood. One last idea includes doctors using lasers, rather than scalpals, to perform surgery. Lasers cause much less damage to body tissue, thus preventing blood loss due to the use of a scalpal.

Researchers are working hard to develop new techniques to protect people from blood contaminated by disease. Saving one's own blood for later use appears to be a very good idea. What do you think?

Connect to... Chemistry

Artificial blood substances have been developed to use in blood transfusions. They can carry oxygen and carbon dioxide. What other properties must they have to be safe?

SECTION REVIEW

1. Compare autologous and homologous blood transfers.
2. What are two problems with autologous blood banks?
3. **Connect to Chemistry:** Find out what jaundice is. How is it related to blood?

You Decide!

SCIENCE & SOCIETY

When the American Red Cross collects blood from volunteer donors, the blood is screened for the AIDS virus. If a donor is found to have the virus, it is the policy of the Red Cross that that individual is notified. Why would the Red Cross have such a policy? Do you think this policy is a good one?

20-4 Your Lymphatic System

New Science Words

lymphatic system
lymph
lymphocytes
lymph nodes

Objectives

- Describe the functions of the lymphatic system.
- Explain where lymph comes from.
- Explain the role of lymph organs in fighting infections.

Functions of Your Lymphatic System

What is the function of your lymphatic system?

You have learned that blood carries nutrients and oxygen to cells. Molecules of these substances pass through capillary walls to be absorbed by nearby cells. Some of the water and dissolved substances around cells becomes part of tissue fluid between cells. What would happen if this fluid kept collecting in the spaces? The tissue would swell and eventually burst. Obviously, this does not happen. Your **lymphatic** (lihm FAT ihk) **system** collects fluid from body tissue spaces and returns it to the blood through lymph capillaries and larger lymph vessels. This system also contains cells that help your body defend itself against pathogens.

Lymphatic Organs

The lymphatic system carries fluid away from tissues into the lymphatic capillaries found in most tissues. This fluid is known as **lymph** (LIHMF). Lymph enters the cap-

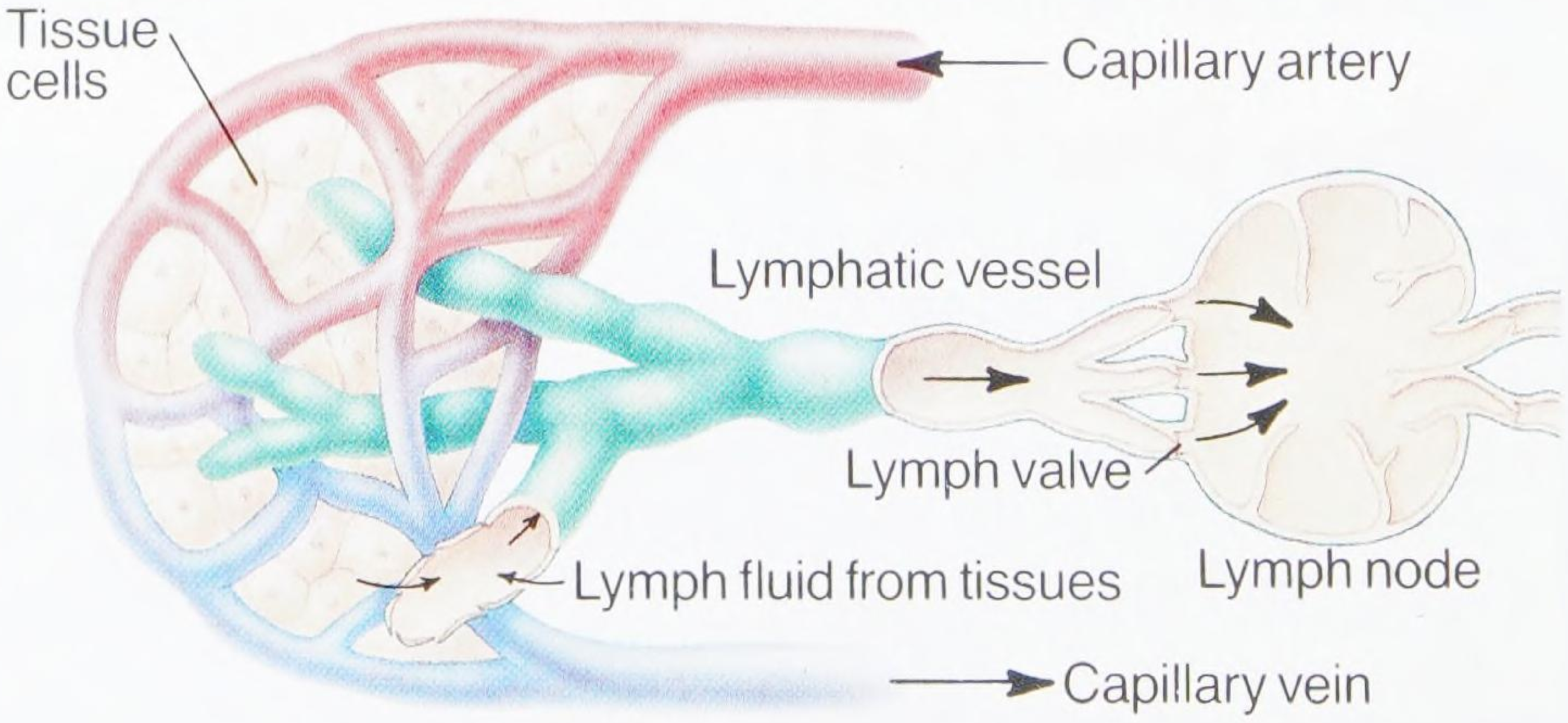


Figure 20-12. Lymph is fluid that has moved from around cells into lymph vessels.

illaries by absorption and diffusion. Lymph consists mostly of water, dissolved substances, and **lymphocytes** (LIHM fuh sites), a type of white blood cell. The lymphatic capillaries join with larger vessels that eventually drain the lymph into large veins near the heart. There is no heartlike structure to pump the lymph through the lymphatic system. The movement of lymph is due to contraction of skeletal muscles and the smooth muscles in lymph vessels. Like veins, the lymphatic vessels have valves that prevent the backward flow of lymph.

Before lymph enters blood, it passes through bean-shaped structures throughout the body known as **lymph nodes.** Lymph nodes filter out microorganisms and foreign materials that have been engulfed by lymphocytes. Sometimes an infection takes over a lymph node. It becomes inflamed and tender to the touch. You have felt an enlarged lymph node in your neck when you've had a cold.

Larger groups of lymph nodes are the tonsils, thymus, and spleen. Tonsils are in the back of the throat. They provide protection to the mouth and nose against pathogens. The thymus is a soft mass of tissue located behind the sternum. The thymus produces lymphocytes that travel to other lymph organs. The spleen is the largest organ of the lymphatic system and is located behind the upper left part of the stomach. Blood flowing through the spleen gets filtered. Here, old, worn out, and damaged red blood cells are broken down. Large, specialized cells in the spleen engulf and destroy bacteria and other foreign substances.

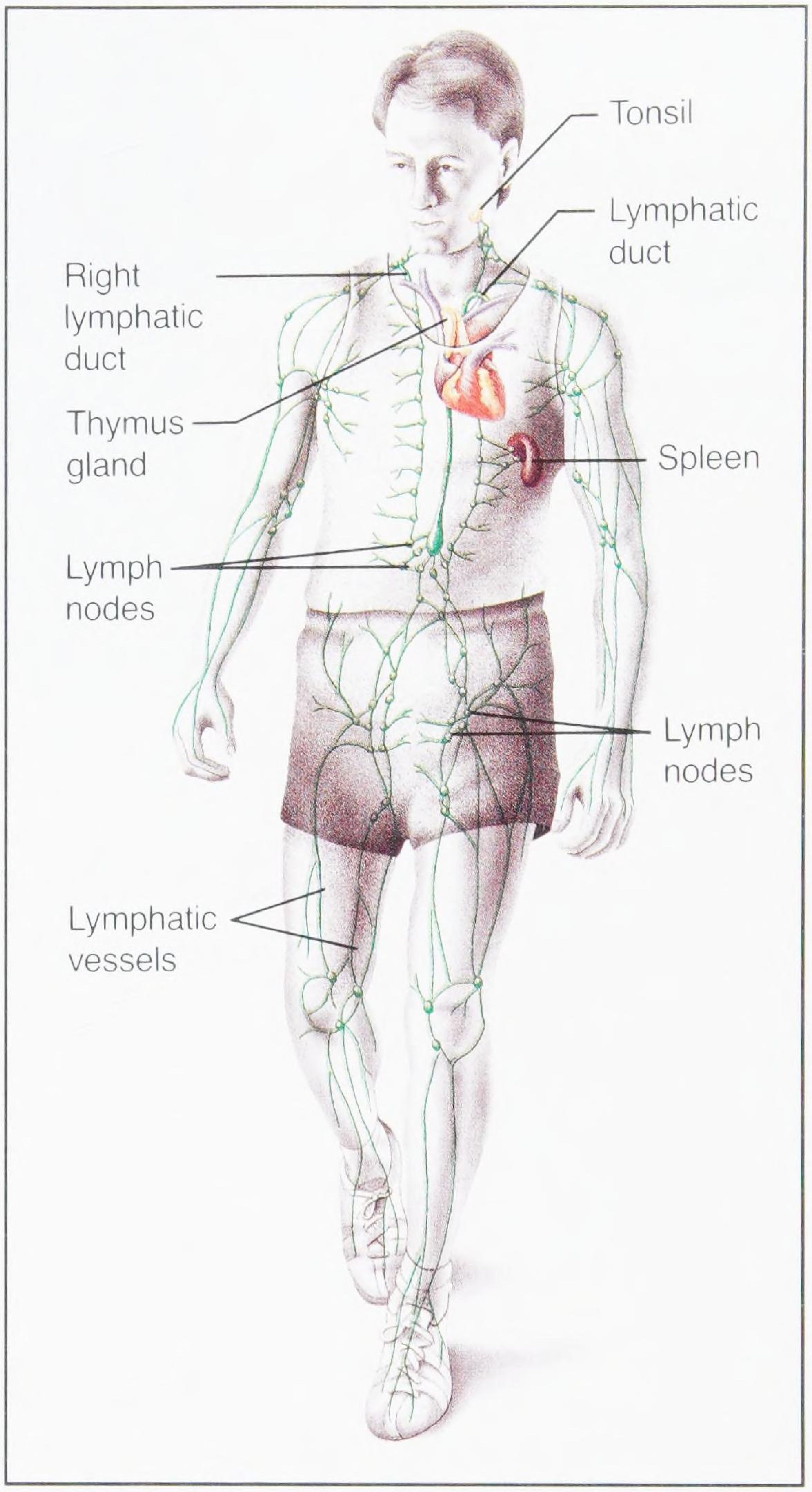


Figure 20-13. The Human Lymphatic System

What is the function of a lymph node?

A Disease of the Lymphatic System

As you read in Chapter 8, the HIV is a deadly virus. When the HIV enters a person's body, it attacks and destroys a particular kind of lymphocyte called helper T cells. Normally, helper T cells help produce antibodies to fight infections. With fewer numbers of helper

Connect to...

Physics

Lymph from the head and neck region of the body flows into veins due to the force of gravity. Find out what gravity is.

Figure 20-14. Ryan White was infected with the HIV when receiving blood transfusions before donated blood was tested for the HIV. Here Ryan (right) is shown with Lukas Haas, who played Ryan in a movie about his life.

T cells, a person is less able to fight pathogens. A person infected with the HIV develops infections that a healthy person would be able to fight. These infections become difficult to treat and often are the cause of death.

Your lymphatic system collects extra fluid from body tissue spaces. It also produces lymphocytes that fight infections from microorganisms and foreign material that enter the body. This system works to keep your body healthy.

SECTION REVIEW

1. Describe the role of your lymphatic system.
2. Where does lymph come from and how does it get into the lymphatic capillaries?
3. What happens when the HIV enters the body?
4. **Apply:** Compare lymphatic vessels and arteries.
5. **Connect to Physics:** When the amount of fluid in the spaces between cells increases, so does the pressure in these spaces. What do you *infer* will happen?

Skill Builder

☑ Comparing and Contrasting

Compare and contrast your lymphatic system and your cardiovascular system. If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.

CHAPTER REVIEW

SUMMARY

20-1: Circulation

1. Arteries carry blood from the heart; capillaries exchange food and oxygen and wastes in cells; veins bring blood back to the heart.

2. Blood enters the right atrium of the heart through veins, moves to the right ventricle, to the lungs by the pulmonary artery. Blood rich in oxygen returns to the left atrium, moves into the left ventricle, and then out through the aorta to the body.

3. Pulmonary circulation is the path of blood to and from the heart and lungs. Circulation through the rest of the body is systematic circulation.

20-2: Blood

1. Red blood cells carry oxygen; platelets form clots; white blood cells fight infection.

2. A, B, AB, and O blood types are determined by the presence or absence of antigens. Correct type transfusion is necessary for survival.

3. In anemia, too little oxygen reaches tissues because of too few red blood cells or too little hemoglobin. In leukemia, larger numbers of white blood cells are produced, none of which can fight disease.

20-3: Science and Society: Autologous Blood Transfusions

1. Autologous blood transfusion is the use of one's own blood for transfusion.

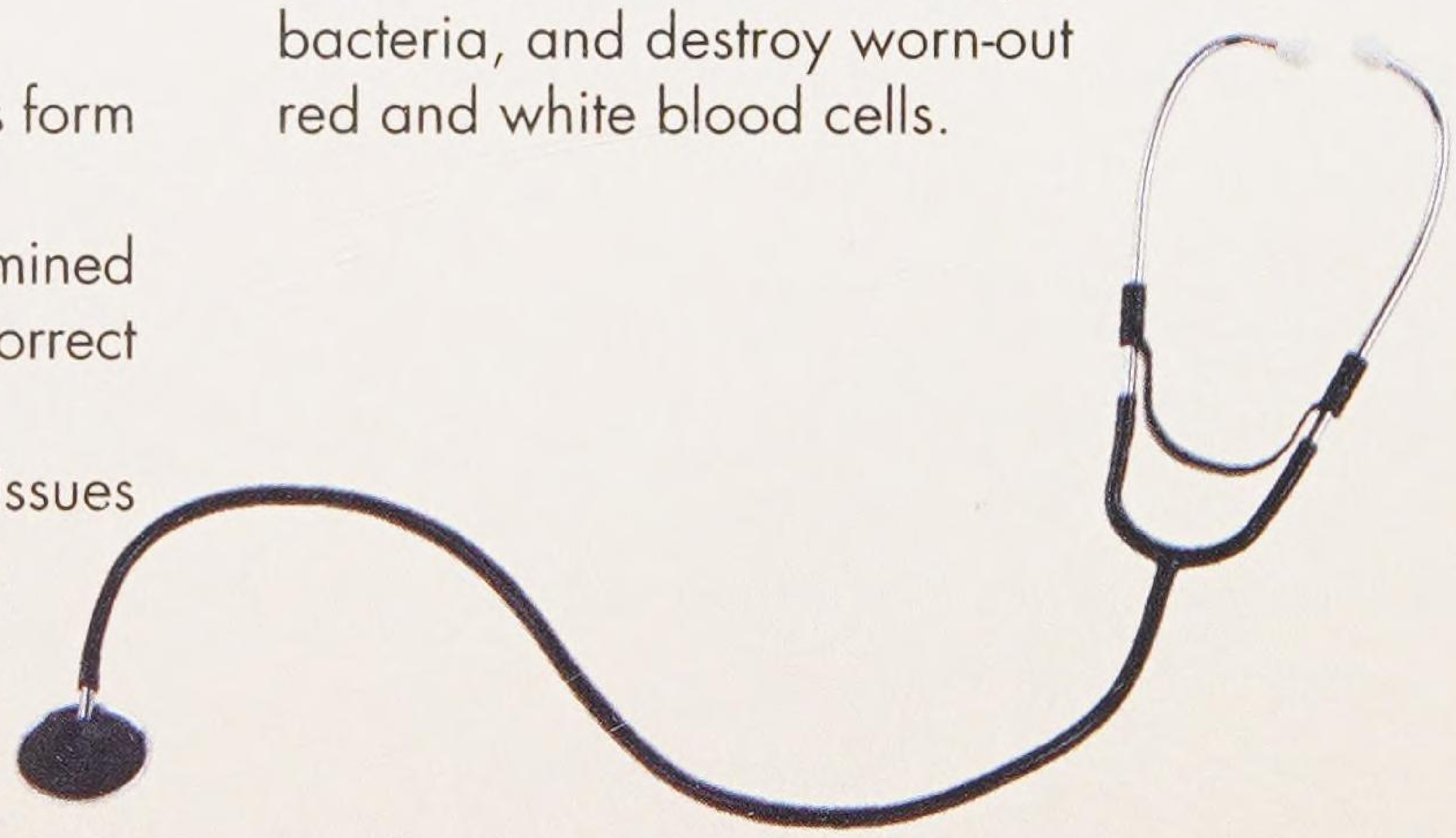
2. Cost of storage and having the blood easily available are problems.

20-4: Your Lymphatic System

1. Lymphatic vessels return fluid to the circulatory system and fight disease.

2. Lymph is fluid between cells.

3. Lymph structures filter blood, produce certain white blood cells that destroy bacteria, and destroy worn-out red and white blood cells.



KEY SCIENCE WORDS

a. **arteries**
b. **atherosclerosis**
c. **atria**
d. **autologous blood transfer**
e. **blood pressure**
f. **capillaries**
g. **coronary circulation**
h. **hemoglobin**
i. **homologous blood transfer**
j. **hypertension**
k. **lymph**
l. **lymphatic system**
m. **lymph nodes**
n. **lymphocytes**
o. **plasma**
p. **platelets**
q. **pulmonary circulation**
r. **systemic circulation**
s. **veins**
t. **ventricles**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. filter microorganisms
2. upper heart chambers
3. vessels connected to the heart ventricles
4. path of blood between heart and lungs
5. path of blood to the heart tissue
6. fatty deposit on artery walls
7. high blood pressure
8. liquid portion of the blood
9. blood vessels that connect arteries to veins
10. active in blood clot formation

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. Exchange of food, oxygen, and wastes occurs through the ______.
   - **a.** arteries **c.** veins
   - **b.** capillaries **d.** lymph vessels
2. Oxygen-rich blood first enters the ______.
   - **a.** right atrium **c.** left ventricle
   - **b.** left atrium **d.** right ventricle
3. Circulation to all body organs is ______.
   - **a.** coronary **c.** systemic
   - **b.** pulmonary **d.** organic
4. Blood is under great pressure in ______.
   - **a.** arteries **c.** veins
   - **b.** capillaries **d.** lymph vessels
5. Blood functions to ______.
   - **a.** digest food **c.** dissolve bone
   - **b.** produce CO_2 **d.** carry oxygen
6. Infection is fought off by ______ cells.
   - **a.** red blood **c.** white blood
   - **b.** bone **d.** nerve
7. In blood, oxygen is carried by ______.
   - **a.** red blood cells **c.** white blood cells
   - **b.** platelets **d.** lymph
8. Clotting of blood requires ______.
   - **a.** plasma **c.** platelets
   - **b.** oxygen **d.** carbon dioxide
9. Type O blood has ______ antigen(s).
   - **a.** A **c.** A and B
   - **b.** B **d.** no
10. The largest filtering lymph organ is (are) the ______.
   - **a.** spleen **c.** tonsils
   - **b.** thymus **d.** node

USING LAB SKILLS

11. The MINI-Lab on page 468 deals with the use of a stethoscope to hear your heart sounds. Use the stethoscope placed on a person's back to listen to the sounds of air moving in and out of the lungs. How does this sound compare with the heart sound?
12. In the Activity on page 477 you compared human blood cells with other vertebrates. Obtain a slide of insect blood cells. How do these blood cells compare with those of humans?.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. A mature human red blood cell has no nucleus. How might this be an advantage?
14. What is the relationship between valves in veins and lymphatic capillaries and gravity?
15. Why would a person with anemia be tired?

APPLY

16. Identify the following as having oxygen-rich or carbon-dioxide full blood: aorta, coronary arteries, coronary veins, inferior vena cava, left atrium, left ventricle, right atrium, right ventricle, superior vena cava.
17. Discuss some benefits of autologous blood transfer.
18. Explain how the lymphatic system works with the cardiovascular system.
19. Why is cancer of the blood or lymph hard to control?
20. Pulse is usually taken at the neck or wrist. Why do you think this is so even though there are many arteries?

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Sequencing:** Put the path of blood in sequence from the heart, to the lungs, and out to the body.
2. **Comparing and Contrasting:** Compare the life span of the different types of blood cells.
3. **Interpreting Data:** Interpret the data obtained in a lab. Find the average heartbeat rate of four males and four females and compare the two averages.
   Males: 72, 64, 65, 72
   Females: 67, 84, 74, 67
4. **Designing an Experiment:** Design an experiment to compare the heartbeat rate at rest and after exercising.
5. **Hypothesizing:** Make a hypothesis to suggest the effects of smoking on heartbeat rate.

PROJECTS

1. With supervision, prepare a heart healthy recipe. Check for recipes through the American Heart Association cookbooks. Bring a sample in to share with the class.
2. Write a report on heart transplants, their success, and what a heart-transplant patient has to do to remain healthy.

CHAPTER

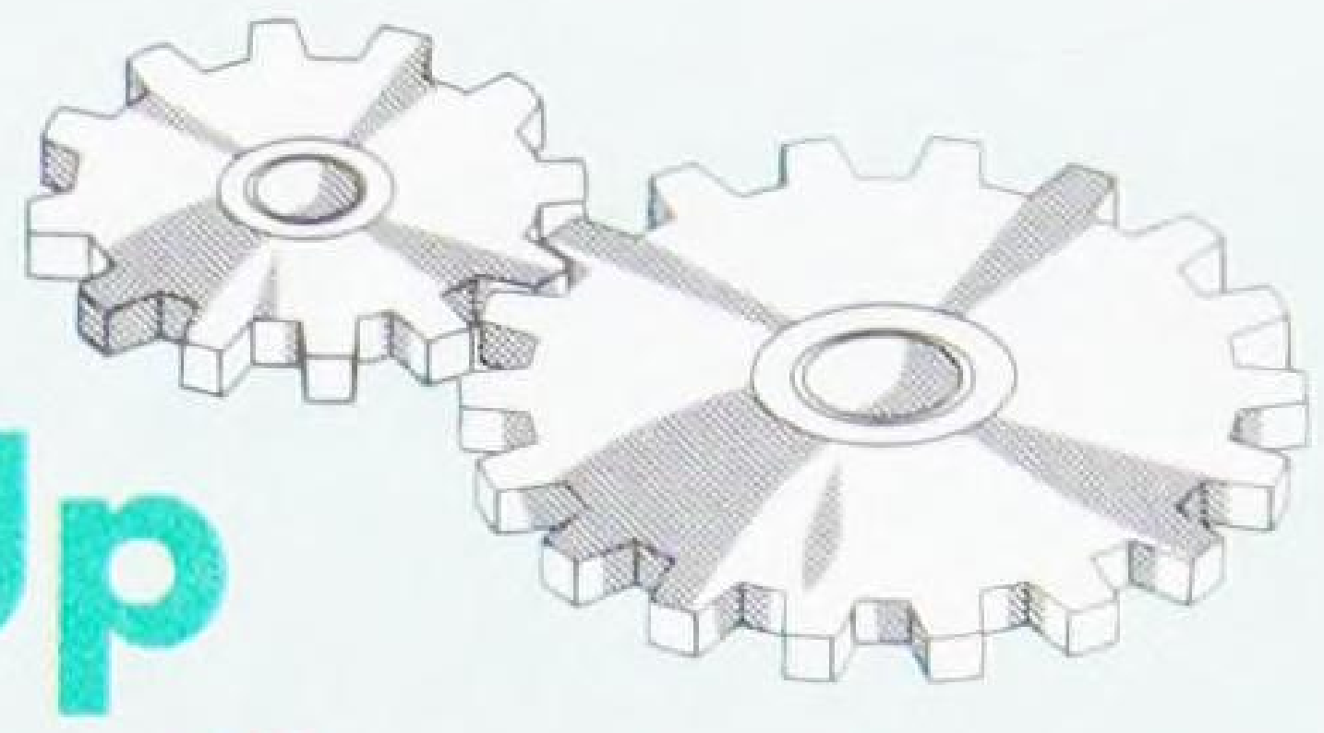
21 Respiration and Excretion

Have you ever run so fast that it felt like your lungs would burst? What did you do to ease your pain and get more air to your lungs? How long did it take your breathing rate to return to normal?

FIND OUT!

Do this activity to find out about your breathing rate.

Put your hand on your chest. Notice your breathing. You can feel your chest move up and down slightly. Take a deep breath. Notice how your rib cage moves out and upward when you inhale. *Count* your breathing rate for 15 seconds. Multiply by four to figure your breathing rate for one minute. Jog in place for one minute and count your breathing rate again. How long does it take for your breathing rate to return to normal? How is your breathing rate *related* to activity?



Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 21-1 Your Respiratory System
- Functions of Your Respiratory System
- Organs of Your Respiratory System
- How You Breathe
- Diseases and Disorders of the Respiratory System

Section 21-2 Science and Society Dangerous Breathing
- Watch Where You Exercise

Section 21-3 Your Urinary System
- Functions of Your Urinary System
- Organs of Your Urinary System
- Other Excretory Organs
- Diseases and Disorders of the Urinary System

Previewing Science Skills

- In the **Skill Builders,** you will sequence, outline and make a concept map.
- In the **Activities,** you will observe, analyze, and collect data.
- In the **MINI-Labs,** you will observe, interpret, diagram, and describe.

What's next?

Now that you know that exercise and breathing rate are related, find out how your body uses the air you breathe. Also learn how your body gets rid of liquid wastes through your lungs, skin, and kidneys.

21-1 Your Respiratory System

New Science Words

pharynx
larynx
trachea
bronchi
alveoli
diaphragm
emphysema
chronic bronchitis
asthma

Objectives

- State three functions of the respiratory system.
- Explain how oxygen and carbon dioxide are exchanged in the lungs and in tissues.
- Trace the pathway of air in and out of the lungs.
- Name three effects of smoking on the respiratory system.

Functions of Your Respiratory System

People have always known that air and food are needed for life. However, no one knew what it was about air that made it so vital. In 1771, a British chemist, Joseph Priestley, published the results of some experiments with air. He discovered that a mouse couldn't live in a container in which a candle had previously been burned. He reasoned that a gas in the air had been destroyed when the candle burned. He also discovered that if he put a plant into the container, the gas necessary for life returned in eight or nine days. Then a mouse again could live in this container. Think about photosynthesis. What do you think went on when the plant was in the container? The gas for life was later named oxygen.

Respiration is the process in which energy is released from glucose in cells. People often get the terms *breathing* and *respiration* mixed up. Breathing is the process whereby air moves into and out of lungs. Air contains oxygen, which is carried to cells by your circulatory system. At the same time, your digestive system has prepared a supply of glucose in your cells. Now oxygen, which has made this long journey, goes to work and plays a key role in releasing energy from glucose. At the end of this process, carbon dioxide wastes get carried back to your lungs in your blood. There, it is expelled from your body. Now think about why the first mouse was not able to stay alive in the container.

Did You Know?

Joseph Priestley was also an ordained minister. In the early 1790s, his home in England was burned because he was sympathetic to the French Revolution. In 1794, he emigrated to the United States and settled in Pennsylvania. He died there in 1804.

Organs of Your Respiratory System

How do cilia in your respiratory system help you?

Your respiratory system is made of body parts that help you breathe by taking oxygen into your body and removing carbon dioxide. The major organs of your respiratory system are shown in Figure 21-1. These organs include your nasal cavity, pharynx (FER ingks), larynx, trachea, bronchi, and lungs. Air enters your body through two openings in your nose called nostrils. Hair inside your nostrils traps dust from the air. Your nostrils lead to your nasal cavity, where air gets moistened and warmed. Glands that produce sticky mucus line the nasal cavity. The mucus traps dust, pollen, and other materials. This helps filter the air you breathe. Tiny hairlike structures, called cilia, move mucus and trapped material to the back of the throat where it can be swallowed.

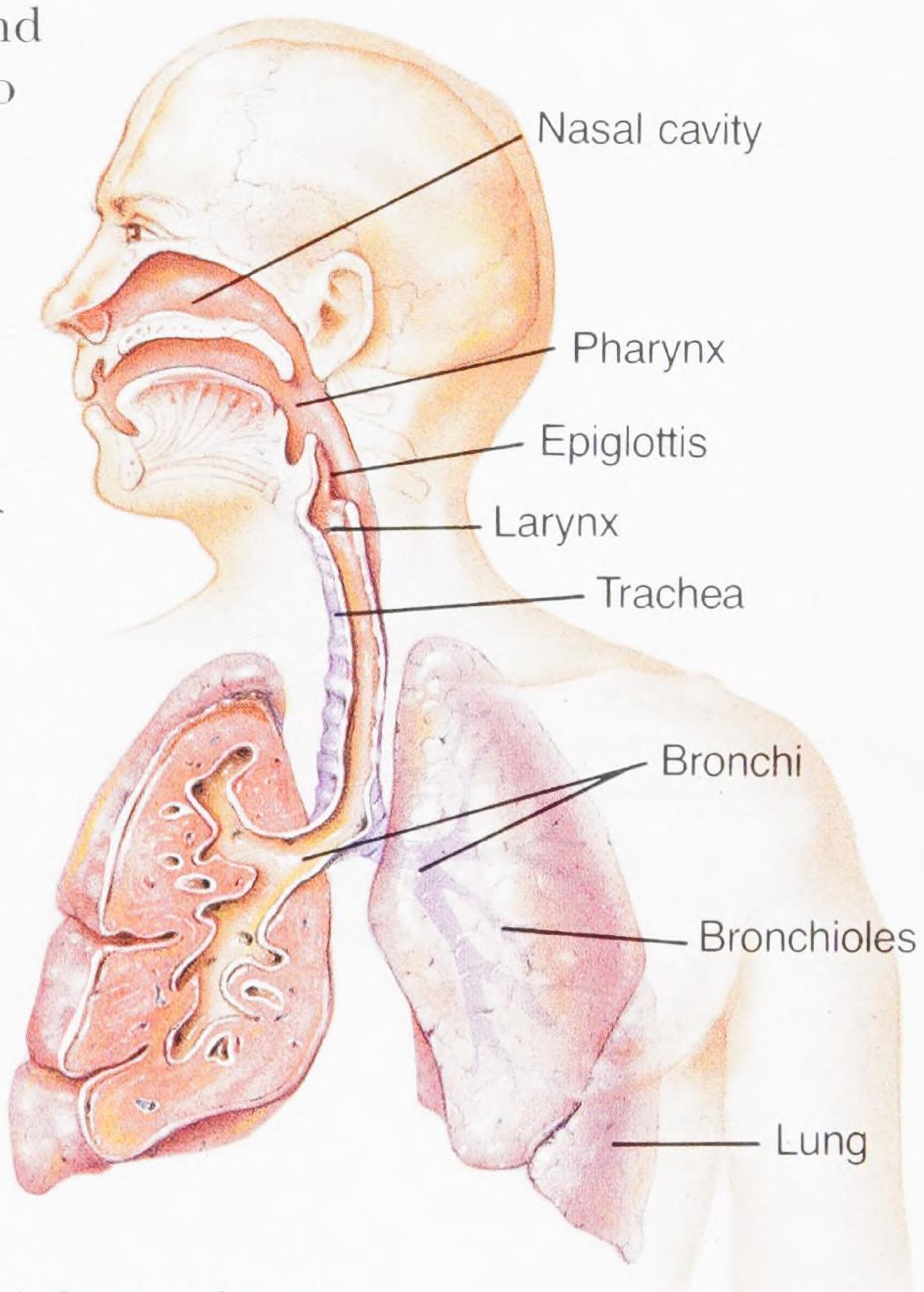


Figure 21-1. The Structures of the Human Respiratory System

Warm, moist air now moves to the **pharynx,** a tubelike passageway for both food and air. The pharynx is located between your nasal cavity and your esophagus. At the lower end of the pharynx is a flap of tissue called the epiglottis (ep uh GLAHT us). When you swallow, the epiglottis closes over your larynx. By doing this, food or liquid is prevented from entering your larynx by accident. The food goes to your esophagus instead. What do you think could happen if you talk or laugh while eating?

How is sound produced?

Between the pharynx and the trachea is a structure called the **larynx,** to which your vocal cords are attached. When you speak, muscles tighten or loosen your vocal cords. Sound is produced when air moves past, causing them to vibrate. The vocal cords of males are longer than those of females.

Below the larynx is the **trachea,** a tube about 12 cm in length. C-shaped rings of cartilage keep the trachea open and prevent it from collapsing. The trachea is lined with mucous membranes and cilia to trap dust, bacteria, and pollen. Why is it necessary for the trachea to stay open all the time?

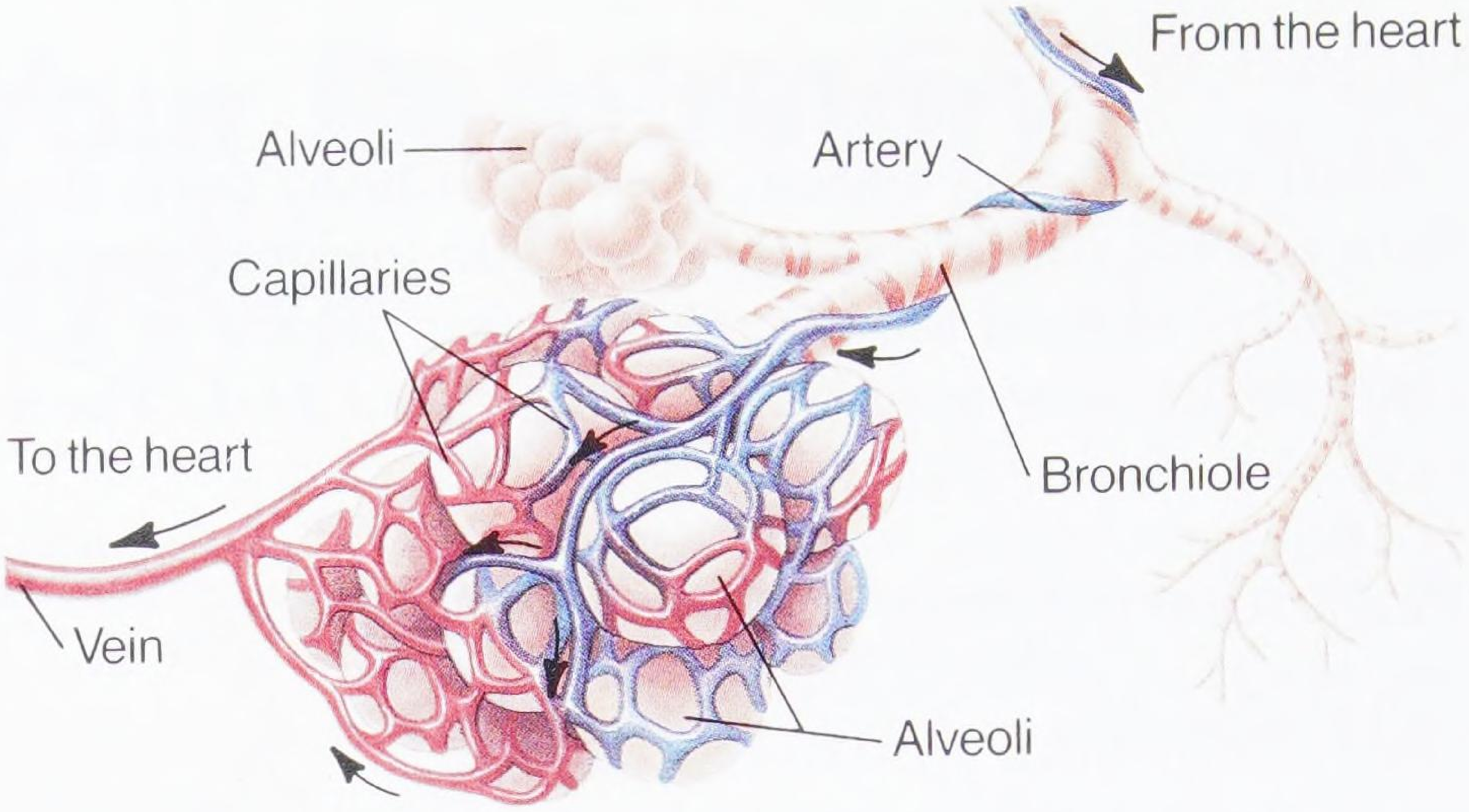


Figure 21-2. In the lungs, alveoli are surrounded by capillaries.

At the lower end of the trachea are two short branches, called **bronchi,** that carry air into the lungs (*singular:* bronchus). Your lungs take up most of the space in your chest cavity. Within the lungs, the bronchi branch into smaller and smaller tubes. The smallest tubes are the bronchioles (BRAHN kee ohlz). At the end of each bronchiole are clusters of tiny thin-walled sacs called **alveoli** (al VE uh li). Your lungs are masses of alveoli arranged in grape-like clusters. Capillaries surround the alveoli. The exchange of oxygen and carbon dioxide takes place between the alveoli and capillaries. This happens easily as the walls of the alveoli and capillaries are only one cell thick. Oxygen diffuses through the walls of the alveoli and then through the walls of the capillaries into the blood. Oxygen is picked up by hemoglobin in red blood cells and carried to all body cells. As this happens, carbon dioxide coming back from body cells diffuses through the walls of the capillaries and through the walls of the alveoli. Carbon dioxide leaves your body when you breathe out, or exhale.

Connect to...

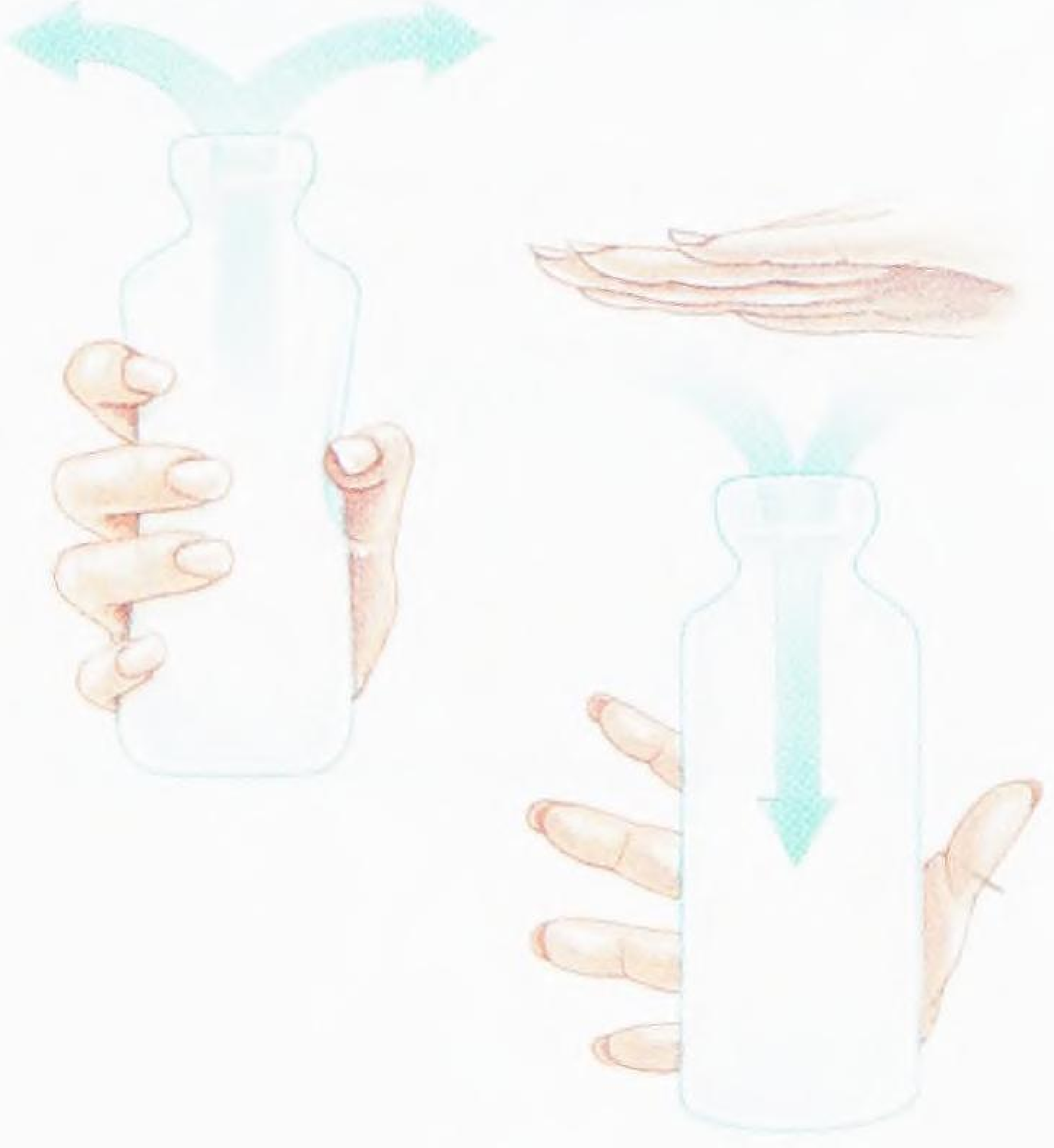
Physics

The surface area of your lungs is about 20 times as great as that of your skin. What does this mean about how well adapted the body is to take in oxygen?

How You Breathe

Breathing is partly the result of changes in air pressure. Under normal conditions, a gas moves from an area of high pressure to an area of low pressure. When you squeeze an empty plastic bottle, air rushes out. This happens because pressure outside the top of the bottle is less than inside the bottle. As you release your grip on the bottle, the pressure inside the bottle becomes less than outside the bottle. Air rushes back in.

Figure 21-3. Air under pressure moves out of a squeezed bottle.



Your lungs work in a similar way to the squeezed bottle. Your **diaphragm** (DI uh fram) is a muscle beneath your lungs that helps move air in and out of your body. Your diaphragm contracts and relaxes when you breathe. Like your hands on the plastic bottle, the diaphragm exerts pressure or relieves pressure on your lungs. Remember earlier when you felt your chest move up and down? When you inhale, your diaphragm contracts and moves down. The upward movement of your rib cage and the downward movement of your diaphragm cause the volume of your chest cavity to increase. Air pressure is reduced in your chest cavity, and your lungs fill with air. Air under pressure outside the body pushes into your air passageways and lungs. Your lungs are somewhat elastic and expand as the air rushes into them.

What causes the movement of your diaphragm?

When you exhale, your diaphragm relaxes and returns to its dome shape. Your rib cage moves downward. These two actions reduce the size of your chest cavity. Your lungs also return to their original position. Pressure on your lungs is increased. The gases inside your lungs are pushed out through air passages.

Even when you exhale forcefully, a little bit of air is always left in your lungs. During times of quiet activity, such as reading or doing homework, your lungs inhale and exhale about 500 mL of air with every breath. When you exercise vigorously, you may inhale and exhale as much as 2000 mL of air per breath.

Science and MATH

At the beginning of this chapter you figured out your breathing rate for one minute. Use this number to *calculate* how many breaths you take in a day. If every two breaths filled a liter bottle, how many bottles would you fill in a day?

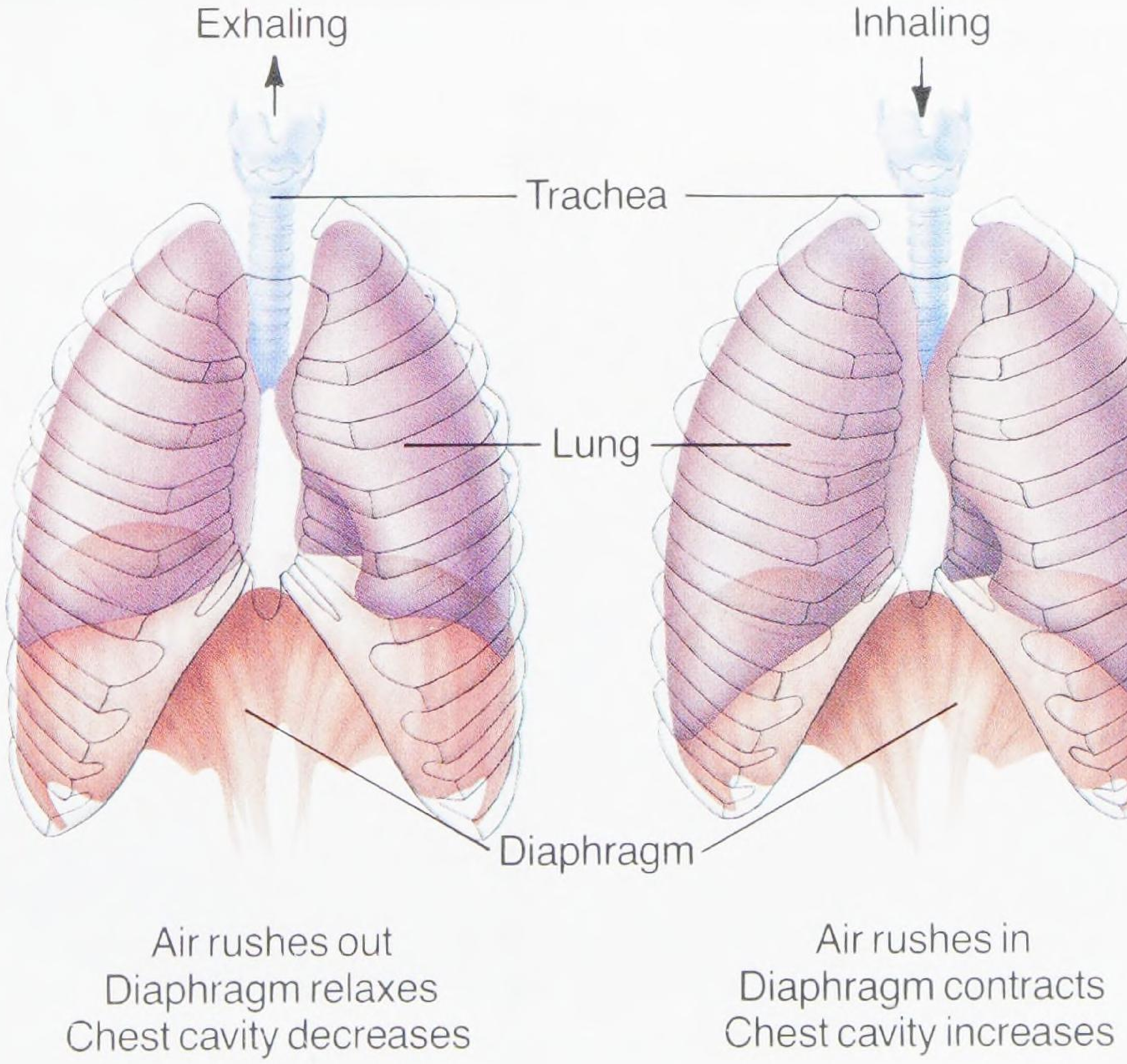


Figure 21-4. When you exhale, your diaphragm relaxes and pushes up on your lungs. When you inhale, your diaphragm contracts and lowers.

Diseases and Disorders of the Respiratory System

Connect to... Earth Science

Black lung is a disease common among coal miners and sand blasters. Find out what causes black lung and how it affects lung tissue.

If you were asked to list some of the things that can harm your respiratory system, you would probably put smoking at the top. Many serious diseases are related to smoking. Being around others who smoke also can harm your respiratory system. Smoking, polluted air, and coal dust have been related to respiratory problems such as emphysema, bronchitis, asthma, and cancer.

What happens when a person has emphysema?

Emphysema (em fuh SEE muh) is a disease in which the alveoli in the lungs lose their ability to expand and contract. Most cases of emphysema result from smoking. When a person has emphysema, smoke becomes trapped in the alveoli in the lungs. This eventually causes the alveoli to stretch and loose their elasticity. As a result, alveoli can't push air out of the lungs. Less oxygen moves into the bloodstream from the alveoli. Blood becomes low in oxygen and high in carbon dioxide. This condition results in shortness of breath. Some people affected with emphysema can't blow out a match or walk up a flight of stairs. Because the heart works harder to supply oxygen to body cells, people who have emphysema often develop heart problems as well.

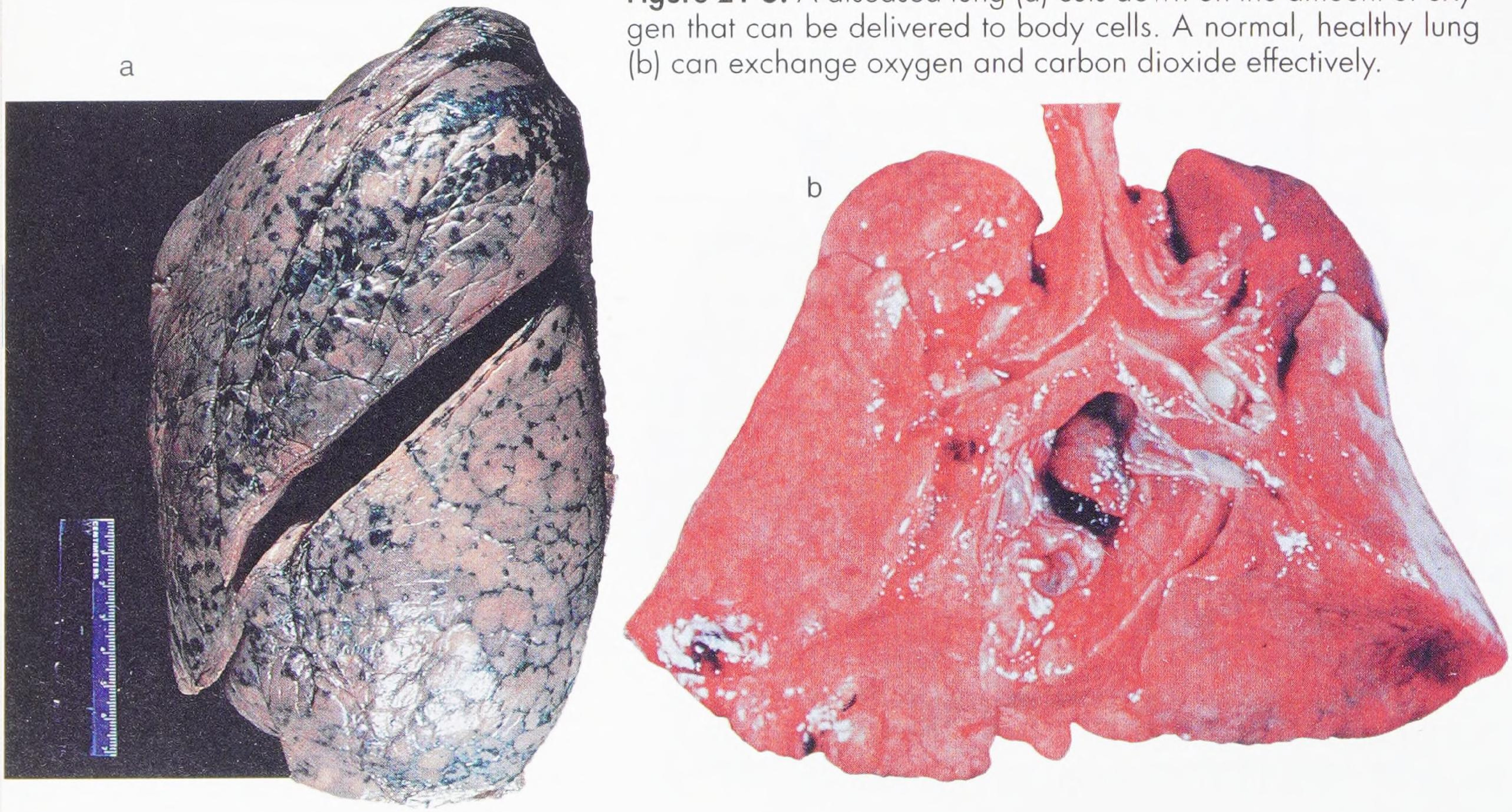
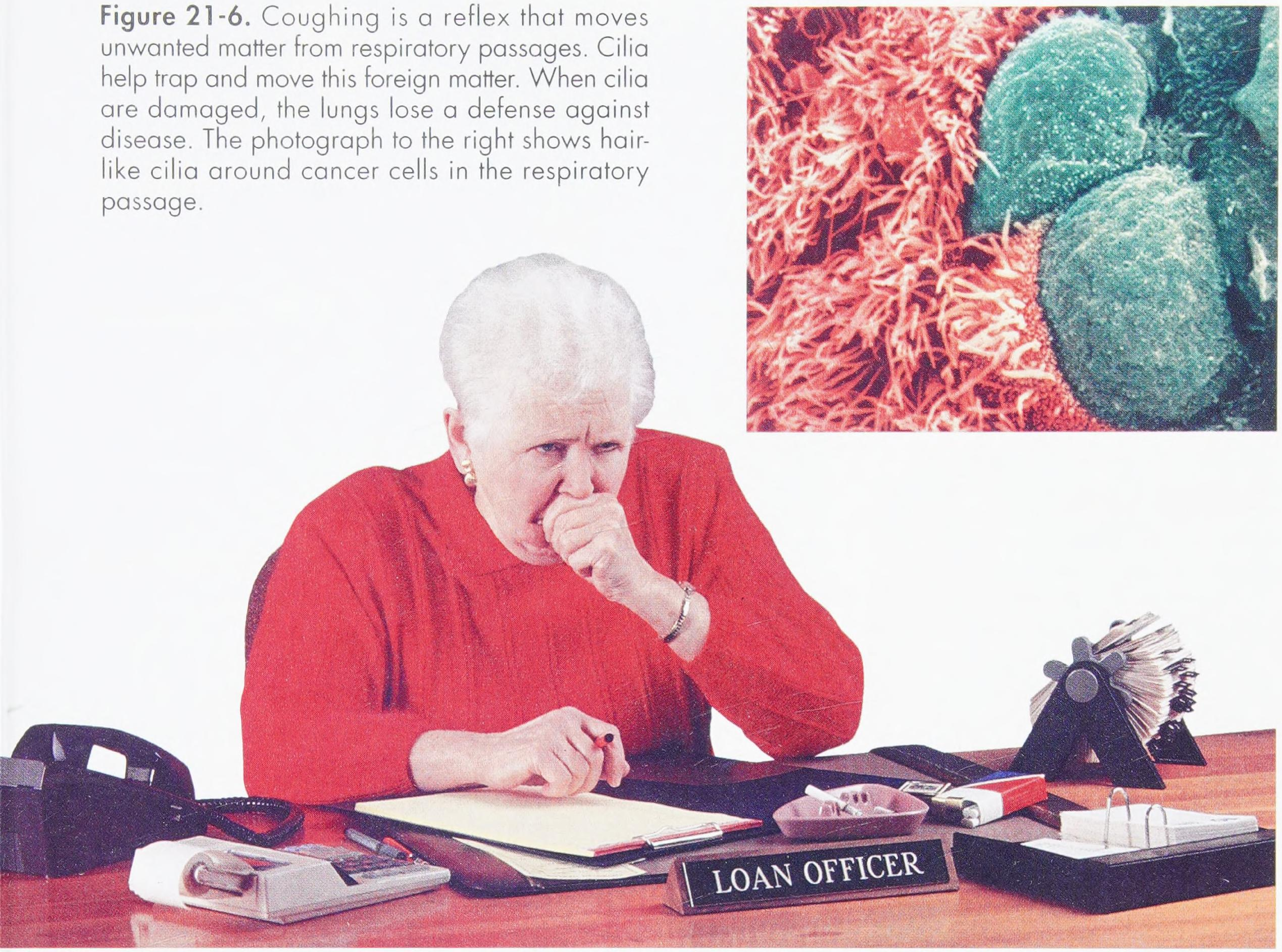


Figure 21-5. A diseased lung (a) cuts down on the amount of oxygen that can be delivered to body cells. A normal, healthy lung (b) can exchange oxygen and carbon dioxide effectively.

Figure 21-6. Coughing is a reflex that moves unwanted matter from respiratory passages. Cilia help trap and move this foreign matter. When cilia are damaged, the lungs lose a defense against disease. The photograph to the right shows hair-like cilia around cancer cells in the respiratory passage.



Chronic bronchitis is a disease in which too much mucus is produced in the bronchial tubes. Most cases of this disease result from smoking. People who have chronic bronchitis cough often to try to clear the mucus from the airway. However, the more a person coughs, the more the cilia and bronchial tubes can be harmed. When cilia are damaged, their ability to move mucus, bacteria, and dirt out of the lungs is impaired. When this happens, harmful substances, such as sticky tar from burning tobacco, build up in the airways.

Asthma is a disorder of the lungs in which there may be shortness of breath, wheezing, or coughing. When a person has an asthma attack, the bronchial tubes contract quickly. Asthma is often an allergic reaction. An asthma attack can result from a reaction to breathing certain substances, such as plant pollen. Eating certain foods or stress have also been related to onset of asthma attacks.

In Your JOURNAL

Write a letter to the local office of the American Lung Association. Find out more about a particular respiratory disease. **In your Journal,** write about the causes of the disease, its symptoms, and treatment. Include information on how many people have the disease in the United States.

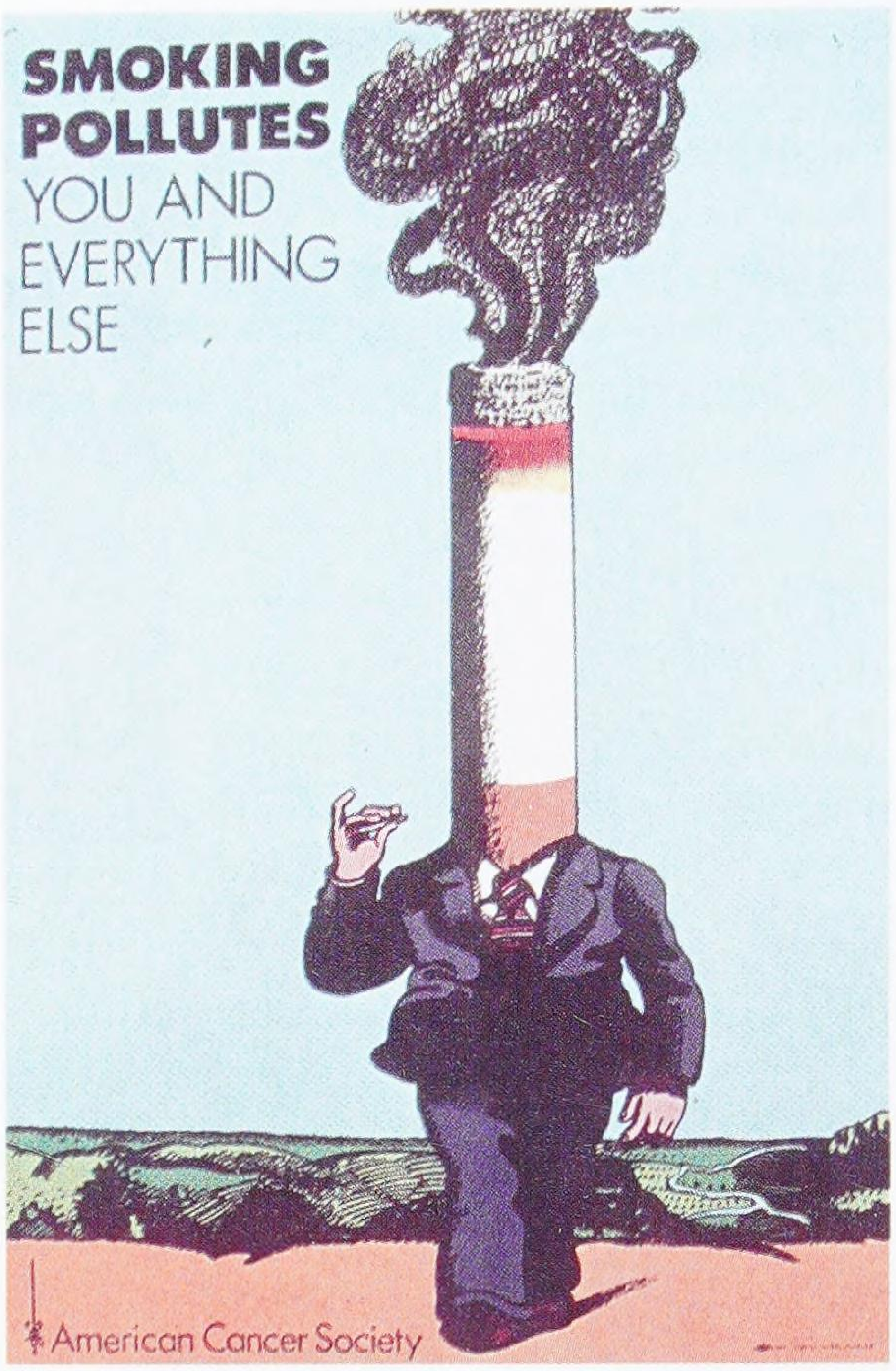


Figure 21-7. Everyone should be aware of the effects of smoking on lungs.

Lung cancer is the leading cause of cancer deaths in men and women in the United States. Inhaling the tar in cigarette smoke is the greatest contributing factor to lung cancer. Smoking also is believed to be a factor in the development of cancer of the mouth, esophagus, larynx, and pancreas.

Except for certain bacteria, all living things would die without oxygen. Your respiratory system takes in oxygen and gets rid of carbon dioxide. This system also helps get rid of some pathogens. You can help keep your respiratory system healthy. Avoid smoking and polluted air. Regular exercise helps increase your body's ability to use oxygen.

MINI-Lab

What is percussing?

Have you ever gone to the doctor and had him or her thump you on the back? This is called percussing. A doctor can tell whether a body part is solid or air filled by percussing. Put one hand flat on a partner's back and tap the third finger with the third finger of your other hand. Lungs should make a clear, hollow sound. Pneumonia patients have fluid around their lungs. *Explain* how percussing can help a doctor diagnose the condition of a patient's lungs?

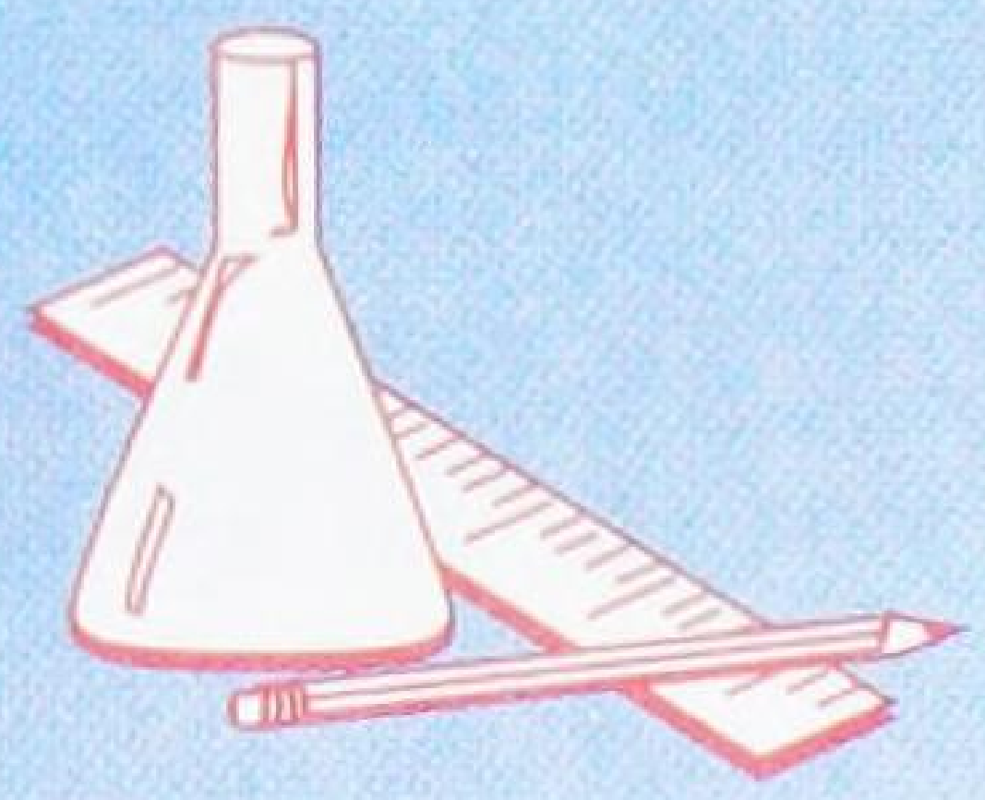
SECTION REVIEW

1. What is the main function of the respiratory system?
2. What happens when oxygen and carbon dioxide are exchanged in the lungs?
3. What causes air to move in and out of the lungs?
4. How does emphysema affect a person's alveoli?
5. **Apply:** How is the work of the digestive and circulatory systems related to the respiratory system?
6. **Connect to Chemistry:** Find out what anemia is. What is its relationship to respiration in cells?

Skill Builder

Sequencing

Sequence the pathway of air through the respiratory organs from the atmosphere to the blood and back to the atmosphere. If you need help, refer to Sequencing in the **Skill Handbook** on page 680.



ACTIVITY 21-1

The Effects of Respiration

Problem: *How does exercise affect the amount of carbon dioxide exhaled by the lungs?*

Materials

- clock or watch with second hand
- drinking straw
- 200 mL bromothymol blue solution
- 400-mL beakers (2)
- graduated cylinder

Procedure

1. Make a table like the one shown.
2. *Predict* how exercise will affect the amount of carbon dioxide exhaled by the lungs.
3. Label beaker A and beaker B. Pour 100 mL bromothymol blue solution into each of the beakers. Bromothymol blue will turn yellow when carbon dioxide is added to it.
4. Look at the clock and begin timing. Exhale through the straw into the bromothymol blue solution in beaker A. **CAUTION:** *Do not inhale through the straw.* Continue exhaling for 15 seconds or until the bromothymol blue solution changes color. Record the time it takes for the color change to occur. Set beaker A aside.
5. Now run in place for three minutes.
6. Exhale into the bromothymol blue solution in beaker B. Exhale using the same force as before.
7. Record the time it takes for the bromothymol blue to change color in beaker B.
8. *Compare* your data with the class data.

Data and Observations

Beaker A	
Beaker B	

Analyze

1. What caused the bromothymol blue in the beaker to change color?
2. *Compare* the time it took the bromothymol blue solution to change color before exercise and after exercise. Explain any difference.
3. What was the control in this experiment?

Conclude and Apply

4. How does exercise *relate* to the amount of carbon dioxide exhaled?
5. Why are some waste products of body tissues exhaled through the lungs?
6. **Hypothesize** a relationship between strenuous excercise and increased breathing rate.

SCIENCE & SOCIETY

21-2 Dangerous Breathing

New Science Words

nitrogen dioxide

Objectives

- State two reasons why exercise is important to good health.
- Become aware of the dangers of exercising in environments that are polluted.

Watch Where You Exercise

You probably realize that exercise is important for good health. When you participate in regular exercise, you feel good, your muscle tone improves, and fat is lost. With regular exercise, lungs become capable of holding greater amounts of air.

What happens to your lungs with regular exercise?

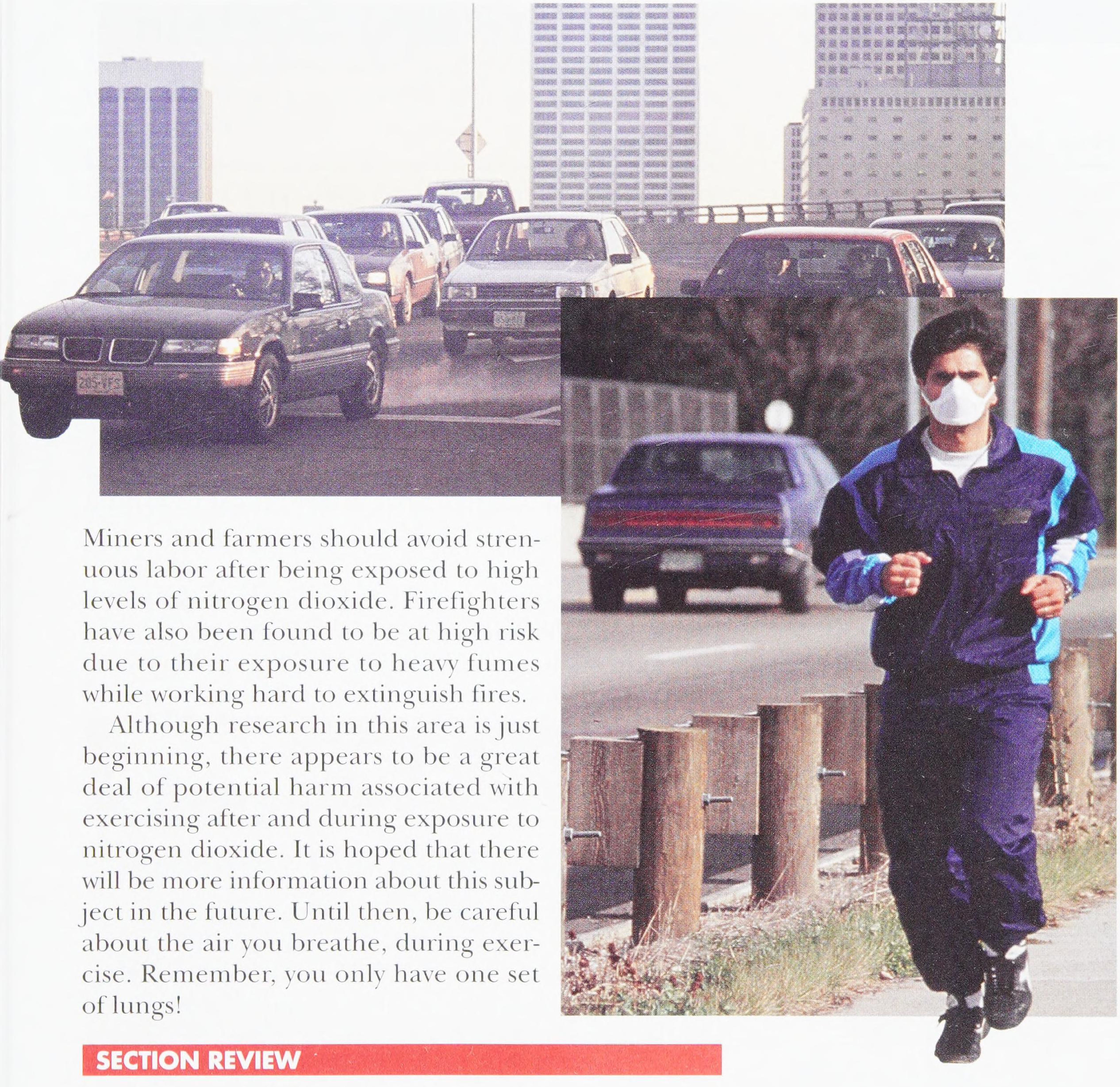
Many people participate in aerobics or go jogging during lunch or after school or work. Unfortunately, busy city streets and parks where people exercise can be polluted with exhaust fumes. Although most people realize that it is not healthful to breathe polluted air, it actually may be more dangerous to do so while exercising.

Two scientists at the Los Alamos National Laboratory in New Mexico discovered that exercising in polluted environments can be dangerous to your health. **Nitrogen dioxide,** found in cigarette smoke and automobile exhaust, is a chemical that is harmful if inhaled. In a research project involving rats exposed to nitrogen dioxide, researchers found that rats that exercised after being exposed to nitrogen dioxide suffered five times more lung damage than those rats that did not exercise after being exposed to the toxins. The rats were exposed to only half of the nitrogen dioxide that a typical smoker breathes in during one puff of a cigarette! This means that exercising in a polluted environment is more harmful than not exercising at all. What does this mean for our society when so many people now exercise by running? Persons who smoke while doing strenuous work or exercises should reconsider their need to smoke. Joggers should avoid areas of heavy traffic.

Connect to... Earth Science

Smog has become a feature of many large cities and even the Grand Canyon. Find out what smog is and what causes it to form.

Nitrogen dioxide also is found in coal mines and in farm silos, where it is given off by decaying plant matter.



Miners and farmers should avoid strenuous labor after being exposed to high levels of nitrogen dioxide. Firefighters have also been found to be at high risk due to their exposure to heavy fumes while working hard to extinguish fires.

Although research in this area is just beginning, there appears to be a great deal of potential harm associated with exercising after and during exposure to nitrogen dioxide. It is hoped that there will be more information about this subject in the future. Until then, be careful about the air you breathe, during exercise. Remember, you only have one set of lungs!

SECTION REVIEW

1. Name two benefits of regular exercise.
2. Name three places where nitrogen dioxide is found.

SCIENCE & SOCIETY

You Decide!

Most restaurants and other public places have designated smoking areas. Some people say smoking should be banned from all public places. How do you feel about this statement? Where do you think people should have the right to smoke?

21-3 Your Urinary System

New Science Words

urinary system
kidneys
nephrons
urine
ureters
bladder
urethra

Objectives

- List three functions of the urinary system.
- Describe how your kidneys work.
- Describe the excretory functions of the skin and lungs.
- Explain what happens when urinary organs don't work.

Functions of Your Urinary System

Waste water in your community is treated after it leaves your home. Filters strain out large materials. Settling basins remove materials that float, and oxygen and chemicals kill bacteria and other organisms that might cause disease.

Your excretory system works in a similar way to the equipment that purifies water. Your excretory organs are your kidneys, lungs, and skin. These organs help your body get rid of wastes. If they didn't do this, you could become very sick from a buildup of toxic substances in cells. Organs could be damaged.

Why is the amount of water in blood important?

The organs of your urinary system are excretory organs. Your **urinary system** is made up of organs that rid your blood of wastes and control blood volume by removing excess water produced by cells. The amount of water in blood is important to maintain normal blood pressure, the movement of gases, and excretion of solid wastes. Your urinary system also balances certain salts and water that must be present in specific concentrations for cell activities to take place.

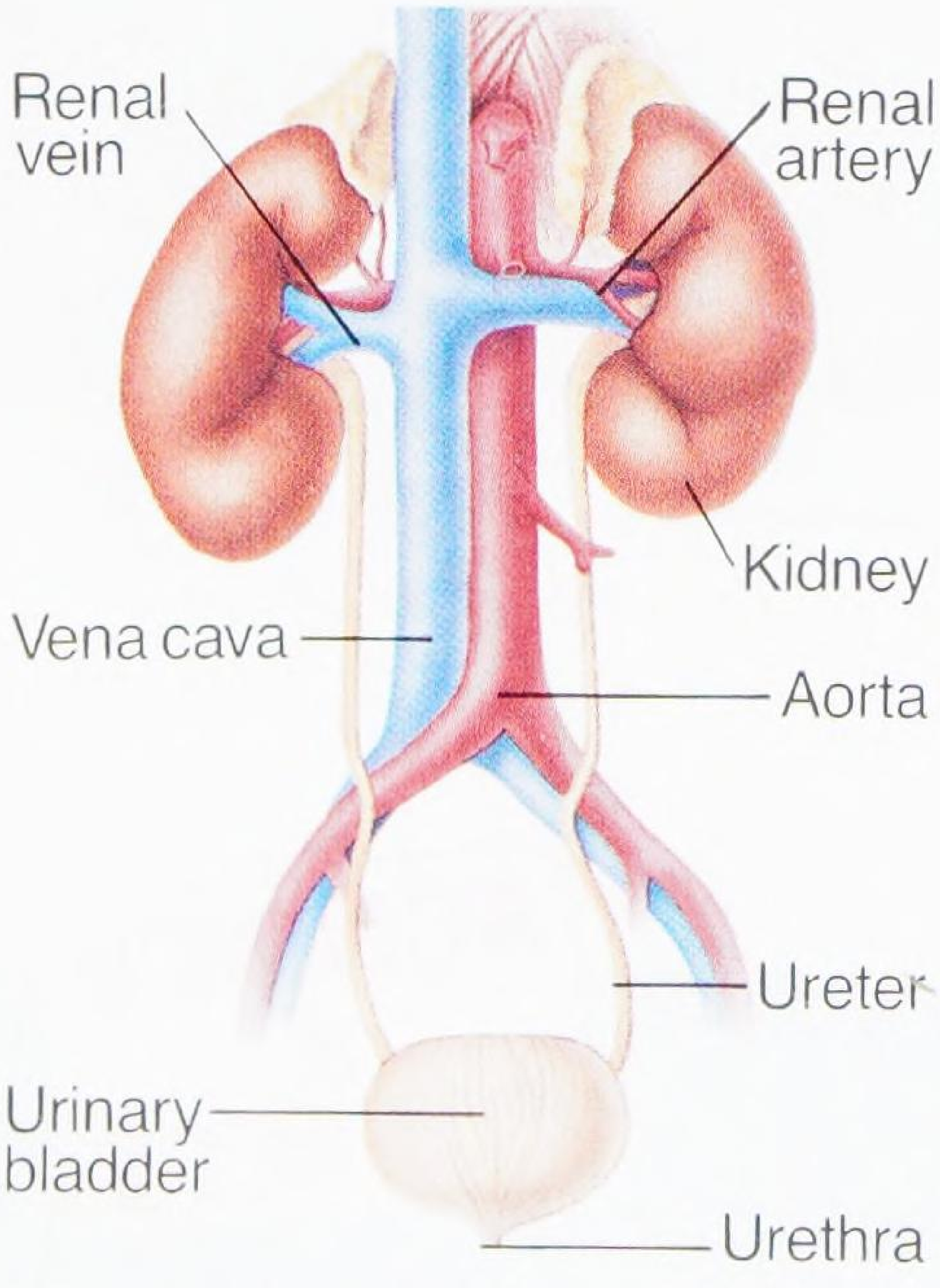


Figure 21-8. Organs of the Urinary System

Organs of Your Urinary System

The major organs of your urinary system are two bean-shaped kidneys. Kidneys are located on the back wall of the abdomen at about waist level. The **kidneys** filter blood that has collected wastes from cells. All of your blood passes through your kidneys many times a day. Figures 21-8 and 21-9 show the structures of the kidneys. Here you can see that blood enters the kidneys through a large artery and leaves through a large vein.

Each kidney is made up of about one million **nephrons** (NEF rahnz), the tiny filtering units of the kidney. Each nephron has a cuplike structure and a duct. Water, sugar, salt, and wastes from your blood pass into the cuplike structure. There, liquid is squeezed into a narrow tubule. Capillaries that surround the tubule reabsorb most of the water, sugar, and salt and return it to the blood. These capillaries merge to form small veins. The small veins merge to form the renal veins, which return purified blood to be circulated throughout your body. The liquid left behind flows into collecting tubules in each kidney. This waste liquid, **urine,** contains excess water, salts, and other wastes. The average adult produces about 1 L of urine per day.

The urine in each collecting tubule drains into a funnel-shaped area of each kidney that leads to the ureters (YOOR ut urz). **Ureters** are tubes that lead from each kidney to the bladder. The **bladder** is a muscular organ that holds urine until it leaves the body. A tube called the **urethra** (yoo REE thruh) carries urine from the bladder to the outside of the body. The amount you lose depends on the amount of fluid you drink.

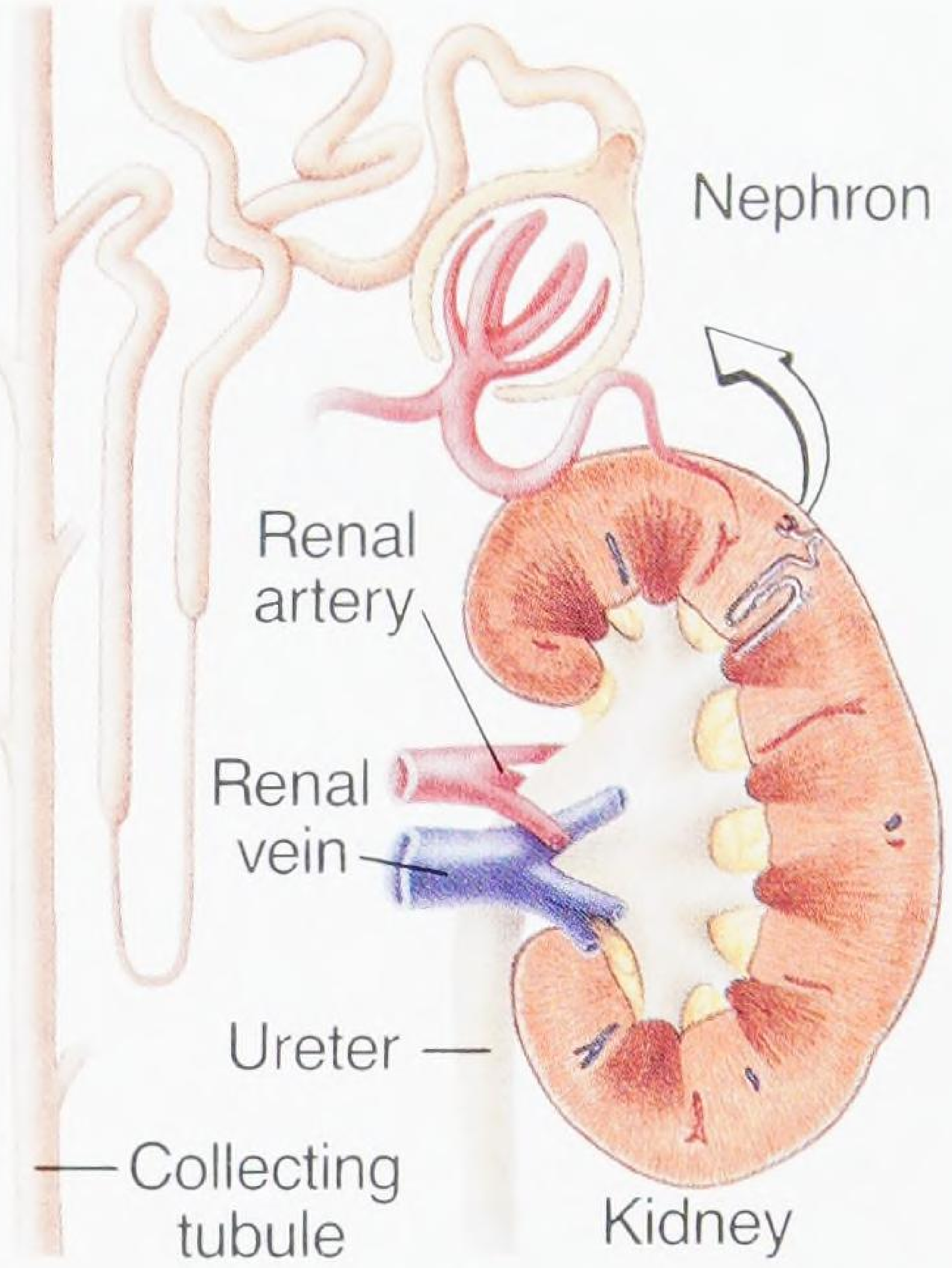


Figure 21-9. The kidneys are made up of many nephrons. A single nephron is shown in detail by the arrow.

PROBLEM SOLVING

Frederick's First Baseball Game

Last summer, Frederick played baseball for the first time in his life. Frederick said, "I had a great time, but it was hard for me to play at times."

Frederick was born without sweat glands. He finds it difficult to stay outdoors for any length of time, especially in the summer. Frederick is not usually able to enjoy a day at the beach or to participate in sports.

However, a local restaurant raised money to develop a "cool suit" for Frederick. The suit resembles a space suit and fits under his clothing. Frederick uses a thermostat to control the pumping of a cool solution through the suit. The suit enables him to spend more time outside.

Think Critically: Explain how the circulating solution keeps Frederick cool.

Other Excretory Organs

Your urinary system helps your body maintain homeostasis with the help of other excretory organs. In Chapter 18, you read that skin releases perspiration to cool your body. Perspiration contains water and small amounts of salt. An adult normally loses up to 0.5 L of water in a day.

Your lungs are excretory organs, too. They remove carbon dioxide produced by cell activity in your body. You also lose water each time you breathe out. The air you exhale has some moisture in it. This is evident when you see your breath on a cold day or breathe on a cold window pane and notice a cloud or fog. Each day about 350 mL of water is removed from your body through your respiratory system.

MINI-Lab

What do kidneys look like?

Examine a model of a kidney or some kidney that your teacher has obtained from a grocery. Carefully cut the tissue in half around the outline of the kidney. Use a magnifying glass to *observe* the internal features of the kidneys or view the features in the model. **In your Journal,** draw and describe what you see. Explain why the kidney is red in color.

Diseases and Disorders of the Urinary System

What happens when someone's urinary organs don't work properly? Waste products that are not removed build up and act as poisons in body cells. Water that would normally be removed from body tissues accumulates and causes swelling of the ankles and feet. Fluids can also build up around the heart. The heart works harder to move less to the lungs. Without elimination, there also could be an imbalance of salts. The body responds by trying to restore this balance. If the balance is not restored, the kidneys and other organs can be damaged.

Persons who have extremely defective kidneys may have to have their blood filtered by an artificial kidney machine in a process called dialysis. During dialysis, blood from an artery is pumped through tubing that is bathed in a salt solution similar to blood plasma. Waste materials diffuse from the tube containing blood and are washed away by the salt solution. The cleaned blood left behind is returned to a vein. A person who has only one kidney can still function normally. One healthy kidney can do the job of two.

Connect to...
Physics

Changes in pressure in blood vessels and nephrons cause fluids to filter from the blood into the kidney or from the kidney into the blood. What substance in blood is excreted and reabsorbed the most?

The urinary system is a purifying unit for the circulatory system. Wastes are filtered from blood as it passes through the kidneys. Some water and salts are reabsorbed to maintain homeostasis. Waste materials, dissolved in water, are eliminated from the body. This system helps to maintain the health of cells and, therefore, the entire body.

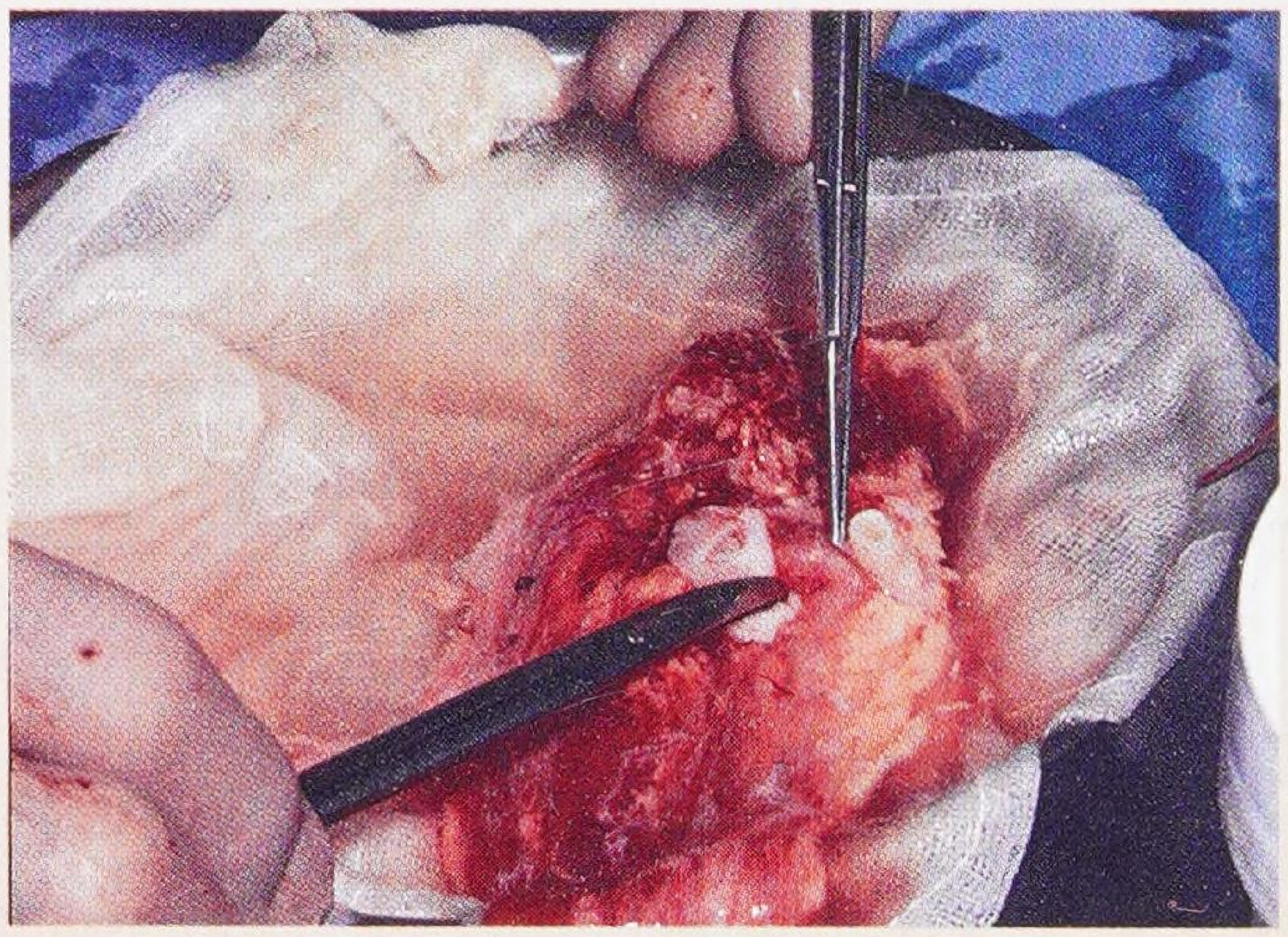
TECHNOLOGY

Kidney Transplants

A person can have just one kidney and still function normally. However, when both kidneys are lost, due to an accident or disease, a kidney transplant is needed. Kidneys from close relatives are preferred for transplants. This is because the relative may have a genetically similar immune system. If this is the case, the patient will be less likely to reject the new kidney.

The donor's kidney is removed and flushed with a sterile solution so that no trace of the donor's blood remains. An incision is made in the patient's abdomen, and the diseased kidney is removed. Then, the new kidney's vessels are stitched to the patient's blood vessels, and the urethra is inserted into the bladder. The operation is simple, but the patient's body will mobilize its immune system against the donor kidney just as it would against an infection. The patient must be given drugs to stop this immune system response.

Think Critically: Why would many transplant patients first suffer more from infection than from organ rejection?



SECTION REVIEW

1. Describe three functions of the urinary system.
2. Explain how the kidneys remove wastes and keep fluids and salts in balance.
3. Why are skin and lungs excretory organs?
4. What happens when urinary organs don't work?
5. **Apply:** Explain why reabsorption of certain materials in the kidneys is important.
6. **Connect to Chemistry:** Find out what urea is. Find out two places in the body where urea is excreted.

Concept Mapping

Skill Builder

Using a network tree concept map, compare the excretory functions of the kidneys and the lungs. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

ACTIVITY 21-2

Sweat Glands in the Skin

Problem: *How are sweat glands distributed on the body?*

Materials

- iodine solution
- bond typing paper
- magnifying lens

Procedure

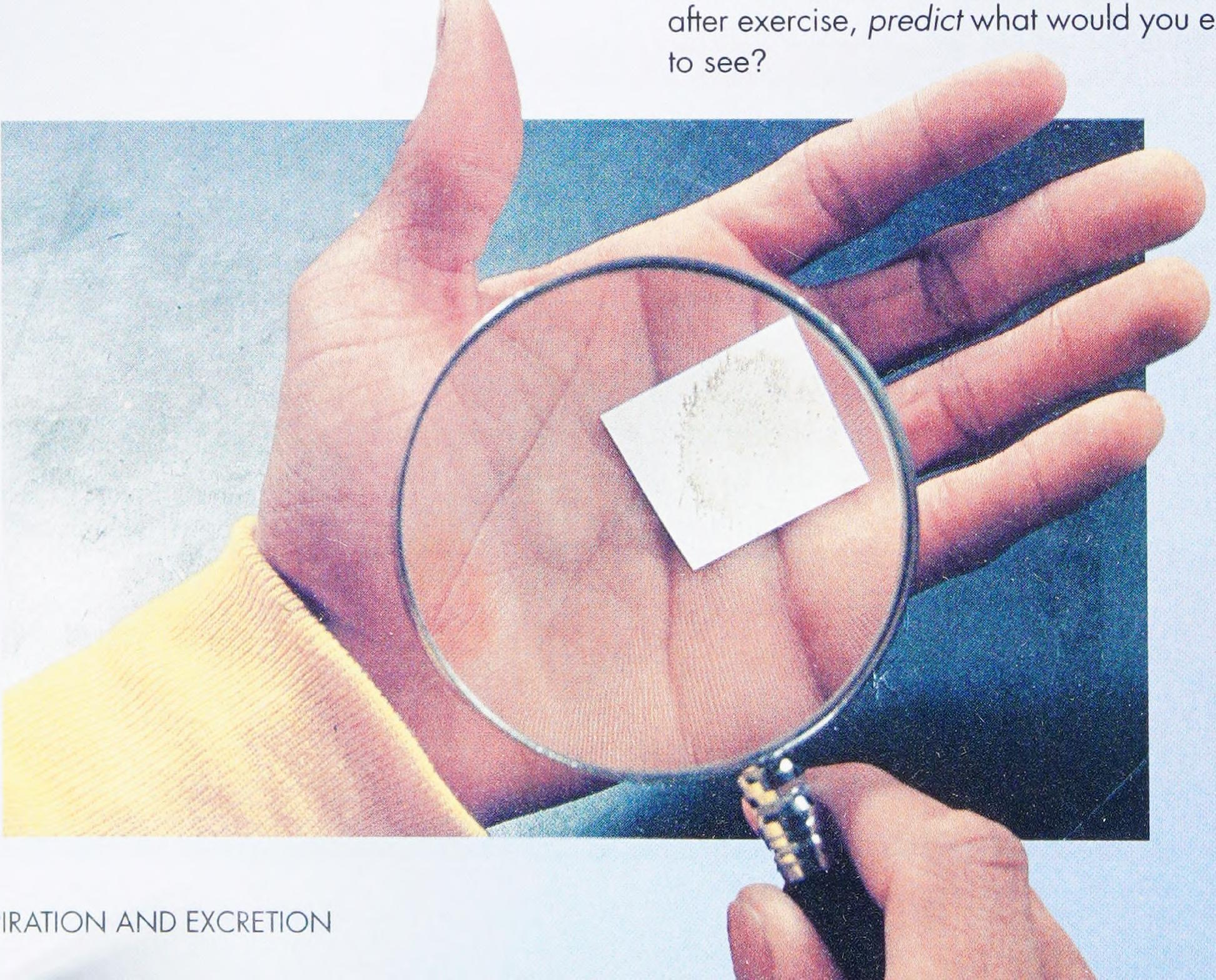
1. Paint a 1 × 1 cm square on the skin of the palm of one hand with two percent tincture of iodine. **CAUTION:** *Iodine is a poison; do not get it in your mouth or eyes. Iodine can stain clothing.*
2. Allow the iodine solution to dry on your skin for three to four minutes.
3. Using the thumb from the other hand, hold a 2 × 2 cm square piece of bond typing paper on the iodine spot for one minute.
4. Lift up the paper and examine it with a magnifying lens. You should see some purple/black dots. Each dot represents a sweat gland. Count the number of dots in 1 square centimeter of the paper.
5. Select another spot, such as the back of the hand or your forearm, to test for sweat gland distribution. Repeat Steps 1 to 4.

Analyze

1. How many dots per centimeter did you observe on the palm of your hand?
2. How many dots per centimeter did you observe on the second spot tested?

Conclude and Apply

3. Bond paper has starch in it. What caused the purple/black dots to appear on the paper?
4. From your observations, *compare* the distribution of sweat glands in different body areas.
5. If this test were done on the palm of your hand after exercise, *predict* what would you expect to see?



CHAPTER REVIEW

SUMMARY

21-1: Your Respiratory System

1. Your respiratory system helps you take oxygen into your lungs and body cells and helps you remove carbon dioxide.

2. Inhaled air passes through the nasal cavity, pharynx, larynx, trachea, bronchi, and into the alveoli of the lungs.

3. Breathing results in part from the diaphragm's movement, which changes the pressure within the lungs.

4. Smoking causes many problems throughout the respiratory system.

21-2: Science and Society: Dangerous Breathing

1. Regular exercise helps your body feel and work well.

2. Exercising in polluted environments can be dangerous to your health.

21-3: Your Urinary System

1. Kidneys filter blood to remove wastes and keep sodium and other chemicals in balance.

2. The kidneys are the major organs of the urinary system; they filter wastes from all of the blood in your body.

3. The skin and lungs are also excretory organs.

4. When kidneys fail to work, dialysis may be used.

KEY SCIENCE WORDS

a. **alveoli**
b. **asthma**
c. **bladder**
d. **bronchi**
e. **chronic bronchitis**
f. **diaphragm**
g. **emphysema**
h. **kidneys**
i. **larynx**
j. **nephrons**
k. **nitrogen dioxide**
l. **pharynx**
m. **trachea**
n. **ureters**
o. **urethra**
p. **urinary system**
q. **urine**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. harmful chemical in auto exhaust
2. clusters of air sacs
3. where vocal cords are attached
4. branches of the trachea
5. muscle involved in breathing
6. disease of broken alveoli
7. a cartilage-reinforced tube through which air moves to the bronchi
8. major urinary organs
9. tubes from kidney to bladder
10. fluid waste

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. When you inhale, your ______ contract(s) and move(s) down.
a. bronchioles **c.** nephrons
b. diaphragm **d.** kidneys

2. Air is moistened, filtered, and warmed in the ______.
a. larynx **c.** nasal cavity
b. pharynx **d.** trachea

3. Exchange of gases occurs between the ______ and capillaries.
a. alveoli **c.** bronchioles
b. bronchi **d.** trachea

4. The rib cage ______ when you exhale.
a. moves up **c.** moves out
b. moves down **d.** stays the same

5. ______ is a lung disorder that may occur as an allergic reaction.
a. Asthma **c.** Emphysema
b. Chronic bronchitis **d.** Cancer

6. A condition worsened by smoking is ______.
a. arthritis **c.** excretion
b. respiration **d.** emphysema

7. ______ are filtering units of the kidney.
a. Nephrons **c.** Neurons
b. Ureters **d.** Alveoli

8. Urine is temporarily held in the ______.
a. kidneys **c.** ureter
b. bladder **d.** urethra

9. About 1 liter of water is lost per day through ______.
a. sweat **c.** urine
b. lungs **d.** none of these

10. All except ______ is(are) reabsorbed by blood after passing through the kidneys.
a. salt **c.** wastes
b. sugar **d.** water

USING LAB SKILLS

11. The Activity on page 495 relates to carbon dioxide exhaled by the lungs. Design an experiment to detect the water vapor exhaled in an hour; in a day.

12. In the Activity on page 502, you determined the distribution of sweat glands on the palms of your hand. Repeat the experiment to determine distribution of sweat glands on the backs of your hands. If there is a difference, suggest an advantage to having more sweat glands on one surface than another.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Why is it better to breathe through your nose?
14. Why does the trachea have cartilage but the esophagus does not?
15. Explain how kidneys maintain homeostasis.
16. Describe how the respiratory and excretory systems maintain homeostasis.

Please ...
It's Breath Taking
Central Ohio
Lung Association

APPLY

17. Compare air pressure in the lungs during inhalation and exhalation.
18. What is the advantage of the lungs having many air sacs instead of being just two large sacs, like balloons?
19. Explain the damage smoking does to cilia, alveoli, and lungs.
20. What would happen to the blood if the kidneys stopped working?

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Making and Using Graphs:** Make a pie graph of total lung capacity.
   - Tidal volume (inhaled or exhaled during a normal breath) = 500 mL
   - Inspiratory reserve volume (air that can be forcefully inhaled after a normal inhalation) = 3000 mL
   - Expiratory reserve volume (air that can be forcefully exhaled after a normal expiration) = 1100 mL
   - Residual volume (air left in the lungs after forceful exhalation) = 1200 mL
2. **Interpreting Data:** Interpret the data below. How much of each substance is reabsorbed into the blood in the kidneys? What substance is totally excreted in the urine?

Substance	Amount moving through kidney to be filtered	Amount excreted in urine
water	125 liters	1 liter
salt	350 grams	10 grams
urea	1 gram	1 gram
glucose	50 grams	0 grams

3. **Recognizing Cause and Effect:** Discuss how lack of oxygen is related to lack of energy.
4. **Hypothesizing:** Hypothesize the number of breaths you would expect a person would take per minute in each situation and give a reason for each hypothesis.
   - while sleeping
   - while exercising
   - while on top of Mount Everest
5. **Concept Mapping:** Make an events chain concept map showing what happens when urine forms in the kidneys. Begin with the phrase, *In the nephron...*

PROJECTS

1. Find out what the Heimlich maneuver is and how it is used in saving lives. How is its success based on the presence of residual air, the small amount of air that is always left in the lungs? Make poster showing the correct procedure and demonstrate the procedure for the class.
2. Contact your local Kidney Foundation for information on dialysis machines and kidney transplants. Ask your teacher if a guest speaker can talk to the class.

CHAPTER

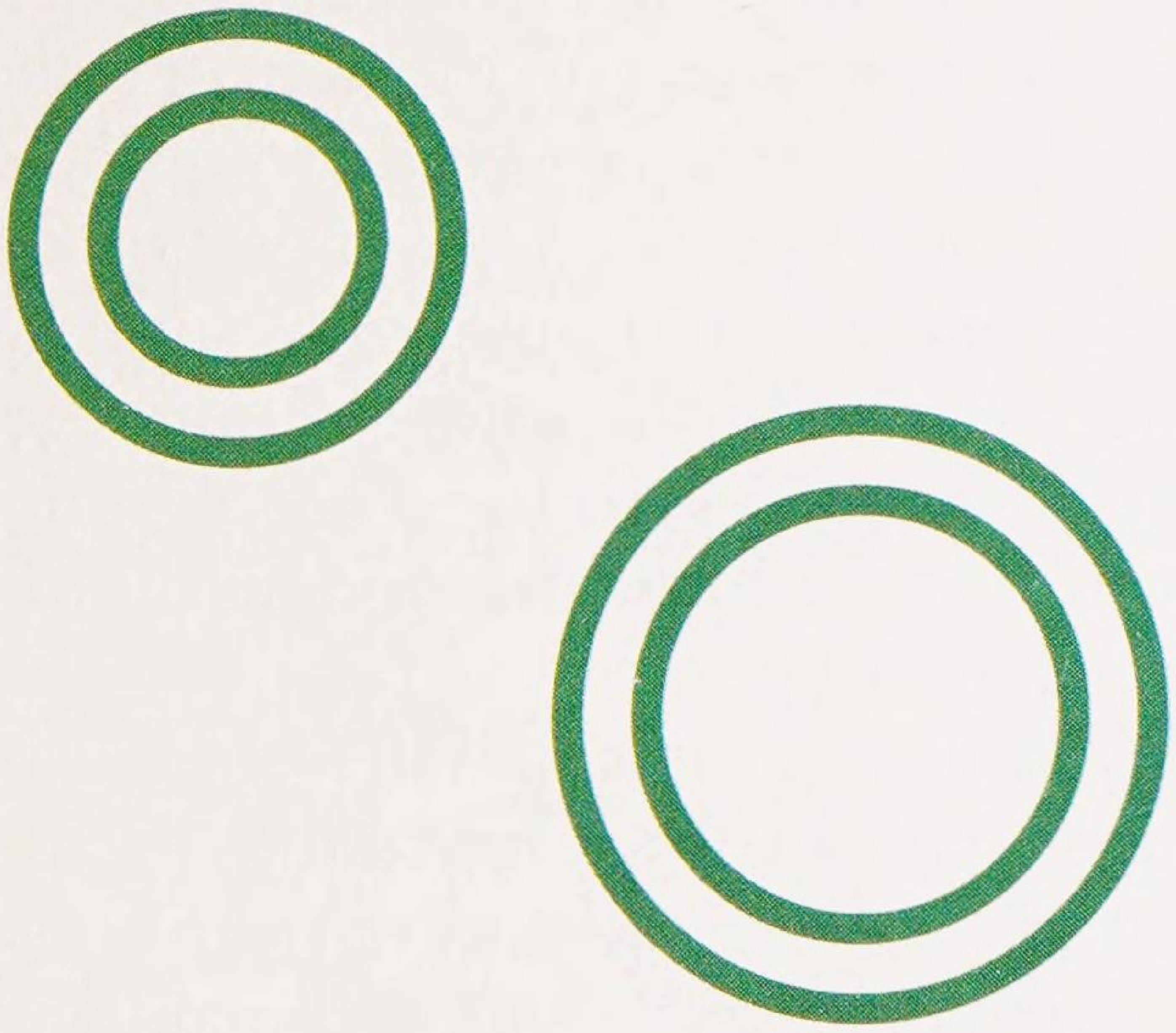
22 Body Regulation

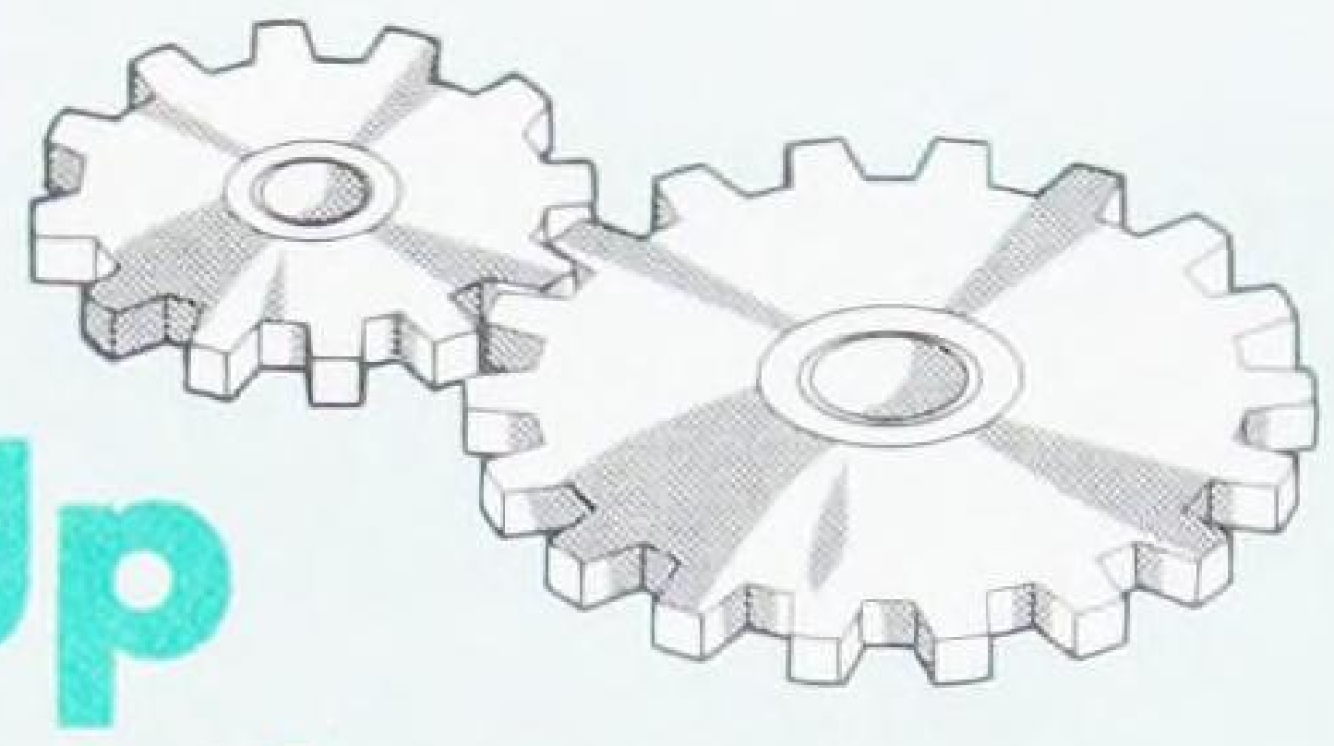
The eye on the page to your left is a complex organ that is your key to the world of vision. Sight is one of the senses that helps you keep in touch with what is going on around you. Do your eyes ever play tricks on you? Have your senses ever fooled you?

FIND OUT!

Do this activity to find out if your senses ever mislead you.

Look at the figure at the bottom of the page. *Estimate* the size difference between the left outer circle and the right inner circle. Now use a metric ruler to measure the sizes of the two circles to determine if their diameters differ. What did you find out?





Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 22-1 Your Nervous System
- The Nervous System at Work
- Divisions of the Nervous System
- Reflexes

Section 22-2 The Senses
- In Touch with Your Environment

Section 22-3 Science and Society Alzheimer's Disease
- What Is Alzheimer's Disease?
- The Cost of Disease

Section 22-4 Your Endocrine System
- Endocrine System
- A Negative Feedback System

Previewing Science Skills

- In the **Skill Builders,** you will make a concept map, make and use tables, and compare and contrast.
- In the **Activities,** you will experiment, predict, measure, and collect data.
- In the **MINI-Labs,** you will experiment and collect and interpret data.

What's next?

Your senses may have misled you in the Find Out activity, but your nervous system generally works to keep you aware and responsive to your environment. In this chapter, you will also learn about chemical control systems that maintain the homeostasis of all other body systems.

22-1 Your Nervous System

New Science Words

neuron
dendrites
axon
sensory neurons
interneurons
motor neurons
synapse
central nervous system
peripheral nervous system
cerebrum
cerebellum
brainstem
reflex

Objectives

- **Describe the basic structure of a neuron and how an impulse moves from one neuron to the next.**
- **Compare the central and peripheral nervous systems and identify their parts and functions.**
- **Interpret the pathway of a reflex.**

The Nervous System at Work

It's your night to do the dishes. To make the job easier, you decide to plug in a favorite tape. About halfway through the chore, you turn to put a plate in the dish drainer and come face to face with your brother wearing an ugly rubber Halloween mask. You scream, and the dish clatters into the sink. Instantly you are out of breath and your hands begin to shake. Your knees feel wobbly, and your heartbeat speeds up. But then, after a few minutes, your breathing returns to normal and your heartbeat is back to its regular rate. What's going on here?

The scene just pictured is an example of how your body responds to changes in its environment and adjusts itself. Your body makes these adjustments with the help of your nervous system. Any change inside or outside your body that brings about a response is called a stimulus. On an average day, you're bombarded by thousands of stimuli. Noise, light, the smell of food in the cafeteria, and the feel of a cold metal doorknob in your hand are all stimuli from outside your body. A growling stomach is an example of an internal stimulus.

How can your body handle all these stimuli at the same time and yet appear so calm? How is it possible for all your systems to work in a coordinated way? Your body has hundreds of internal control systems that maintain homeostasis. Breathing rate, heartbeat rate, and digestion are just a few of the activities in your body that are constantly checked and regulated. Your nervous system and the endocrine system, a chemical control described later in this chapter, are the main mechanisms by which homeostasis is maintained in your body.

MINI-Lab

Who has a better sense of smell?

Design an experiment to test classmates' ability to smell different foods, colognes, and household products. Record their responses in a data table according to sex. *Interpret* your data. Are there differences between males and females in the ability to detect odor?

Neurons

The working unit of the nervous system is the nerve cell, or **neuron.** The neuron in Figure 22-2 is made up of a cell body and branches called dendrites and axons. **Dendrites** receive messages and send them to the cell body. An **axon** carries messages away from the neuron cell body. Any message carried by a neuron is called an impulse.

There are three types of neurons in your body: sensory neurons, motor neurons, and interneurons. **Sensory neurons** receive information and send impulses *to* the spinal cord or brain. Your skin and other sense organs are equipped with structures called receptors that respond to stimuli. These stimuli may be changes in temperature, pain, pressure, odor, sound waves, and chemicals around you. This information is picked up by nearby sensory neurons and sent in the form of impulses to your brain or spinal cord. There, a second type of neuron, an interneuron, passes the impulses to motor neurons. *Inter* means "between." **Interneurons** are nerve cells throughout the brain and spinal cord that relay impulses from sensory neurons to motor neurons. There are more interneurons in your body than the other two types. **Motor neurons** conduct impulses *from* the brain or spinal cord to muscles or glands throughout the body. For instance, when you saw the Halloween mask, sensory receptors in your eyes were stimulated. A message was sent to your brain by way of sensory neurons. Your brain responded by sending back impulses along motor neurons to your muscles. Your heart immediately started to pound and your breathing rate increased. Together, these three types of neurons act like a relay team, moving impulses through your body from stimulus to response.

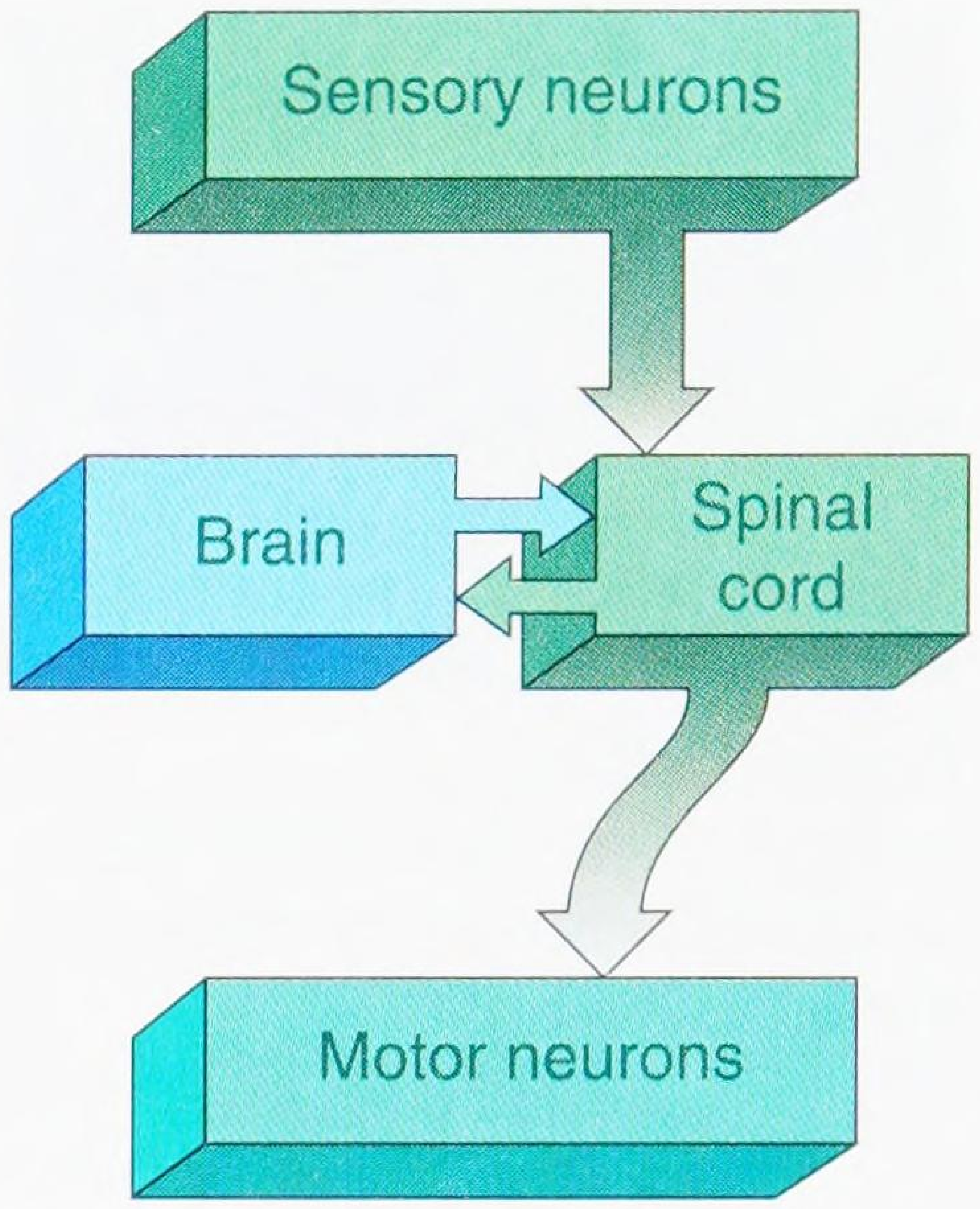


Figure 22-1. In your nervous system, impulses travel a pathway that takes them from sensory neurons to interneurons in your brain and spinal cord to motor neurons.

In what direction do sensory neurons move impulses?

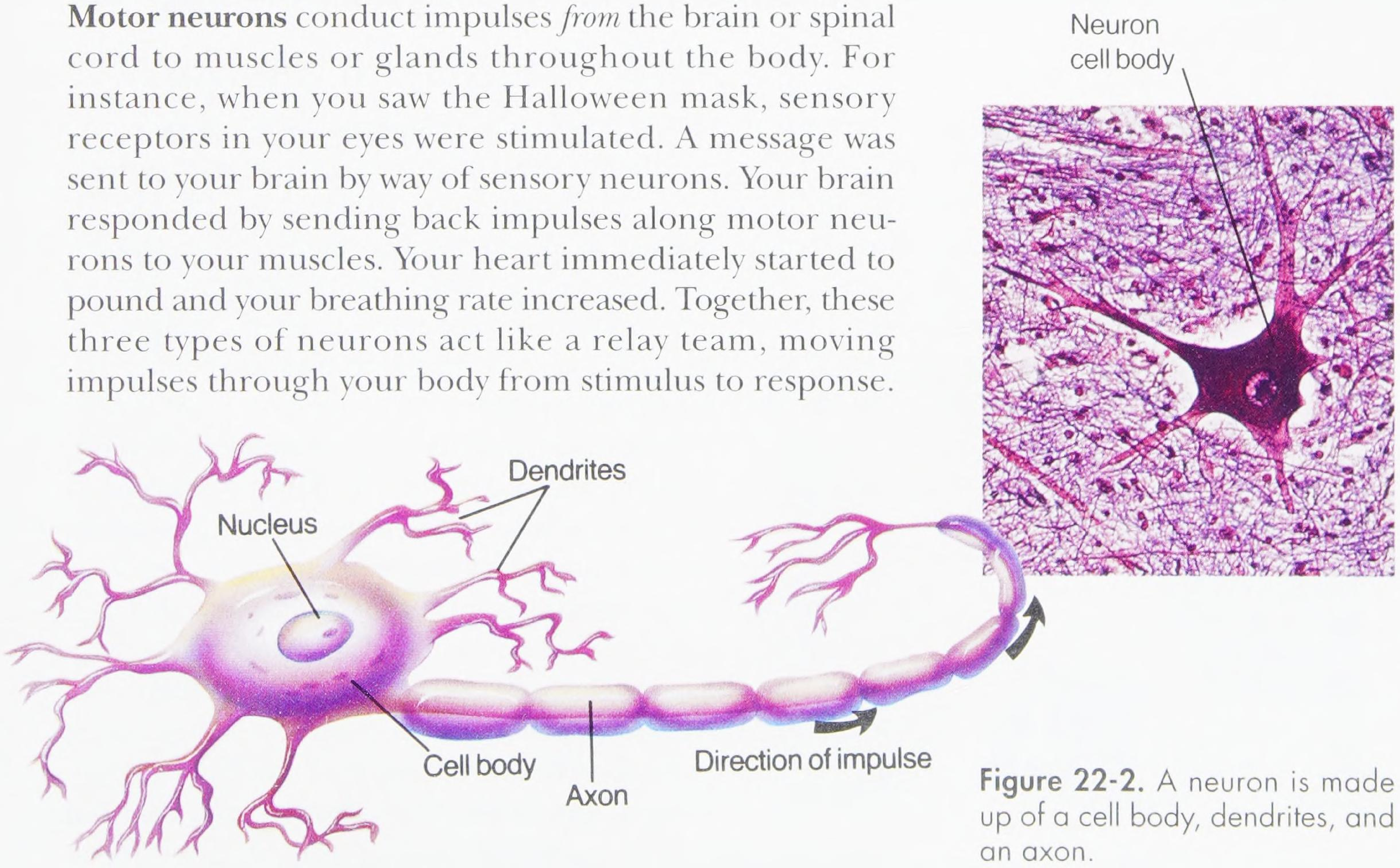


Figure 22-2. A neuron is made up of a cell body, dendrites, and an axon.

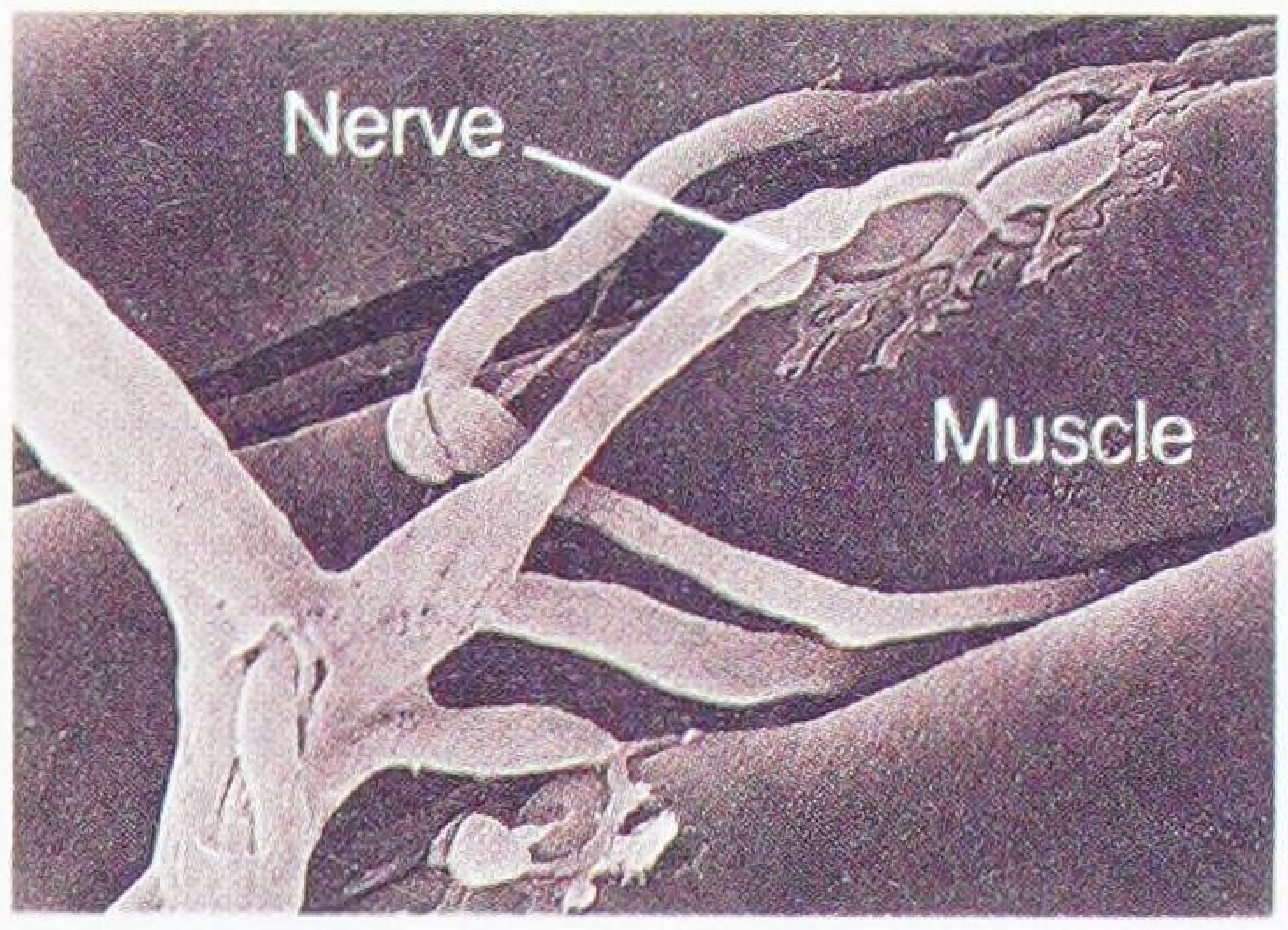
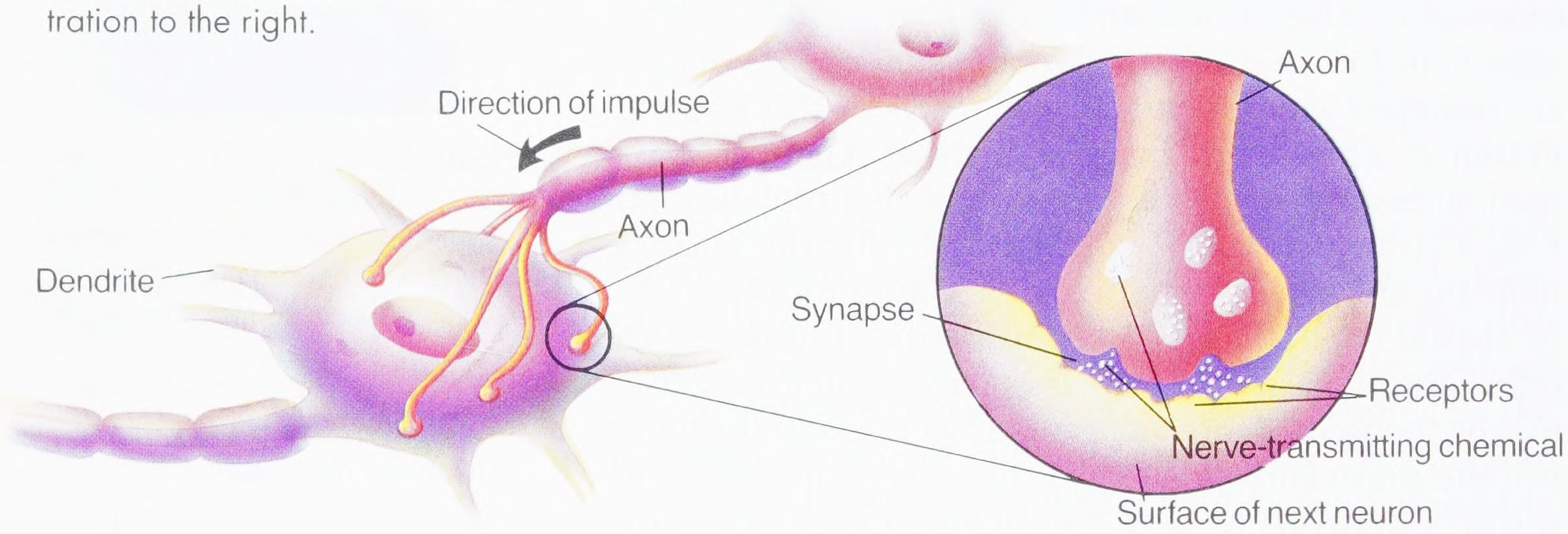


Figure 22-3. Impulses move from neurons to muscle as seen above, or to other neurons as in the illustration to the right.

Synapse

Neurons don't touch each other. How does an impulse move from one neuron to another? To get from one neuron to the next, an impulse jumps across a small space called a **synapse.** In Figure 22-3, you can see that when an impulse reaches the end of an axon, a nerve transmitting chemical is released by the axon. This chemical diffuses across the synapse and starts an impulse in the next neuron. In this way, an impulse moves from one neuron to another.



Divisions of the Nervous System

Organs of the nervous system are grouped into two major divisions: the central nervous system (CNS) and the peripheral nervous system (PNS). The **central nervous system** is made up of the brain and spinal cord. The **peripheral nervous system** is made up of all the nerves outside the CNS, including cranial nerves and spinal nerves. These nerves connect the brain and spinal cord to other body parts.

Connect to... Physics

Nerve impulses can travel at speeds of up to 120 kilometers per second in the body. Compare this to the speed of electricity, which moves at about 300 000 kilometers per second. How many times faster is an electric impulse than a nerve impulse?

The Central Nervous System

Because you have a central nervous system with a brain, your body activities are coordinated. If someone pokes you in the ribs, your whole body is aware. Your neurons are adapted in such a way that impulses move in only one direction. Impulses in sensory neurons move from a receptor to the brain or spinal cord.

The brain is made up of approximately 100 billion neurons. Figure 22-4 shows that the brain is divided into three major parts: cerebrum, cerebellum, and brainstem. The largest part of the brain, the **cerebrum,** is divided into two large sections called hemispheres. Here, impulses from the senses are interpreted, memory is stored, and the work of voluntary muscles is controlled. The outer layer of the cerebrum, the cortex, is marked by many ridges and grooves. The diagram also shows some of the tasks that sections of the cortex control.

A second part of the brain, the **cerebellum,** is behind and under the cerebrum. It coordinates voluntary muscle movements and maintains balance and muscle tone.

The **brainstem** extends from the cerebrum and connects the brain to the spinal cord. It is made up of the midbrain, the pons, and the medulla. The brainstem controls homeostasis of heartbeat, breathing, and blood pressure. It also coordinates involuntary muscle movements.

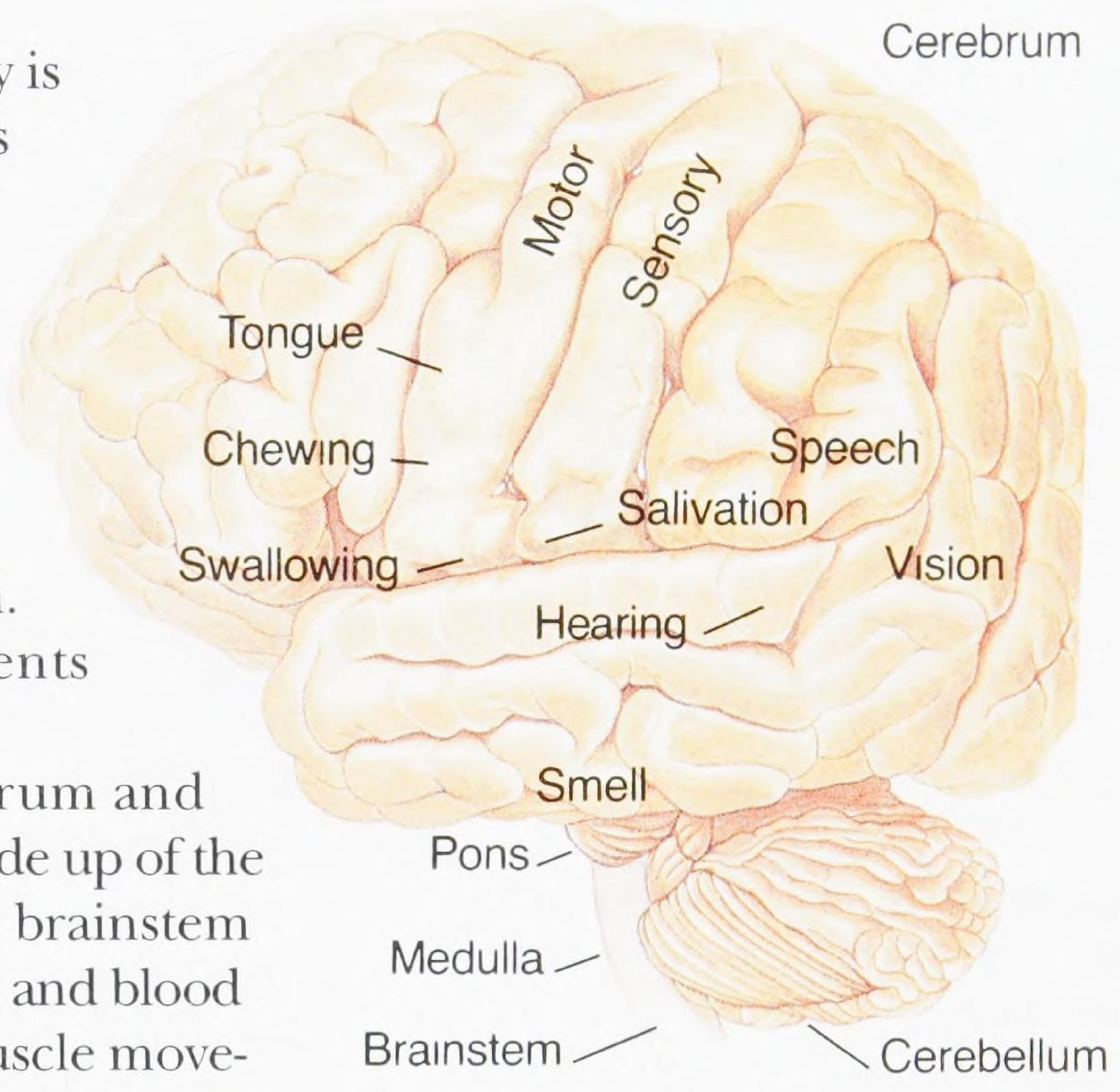


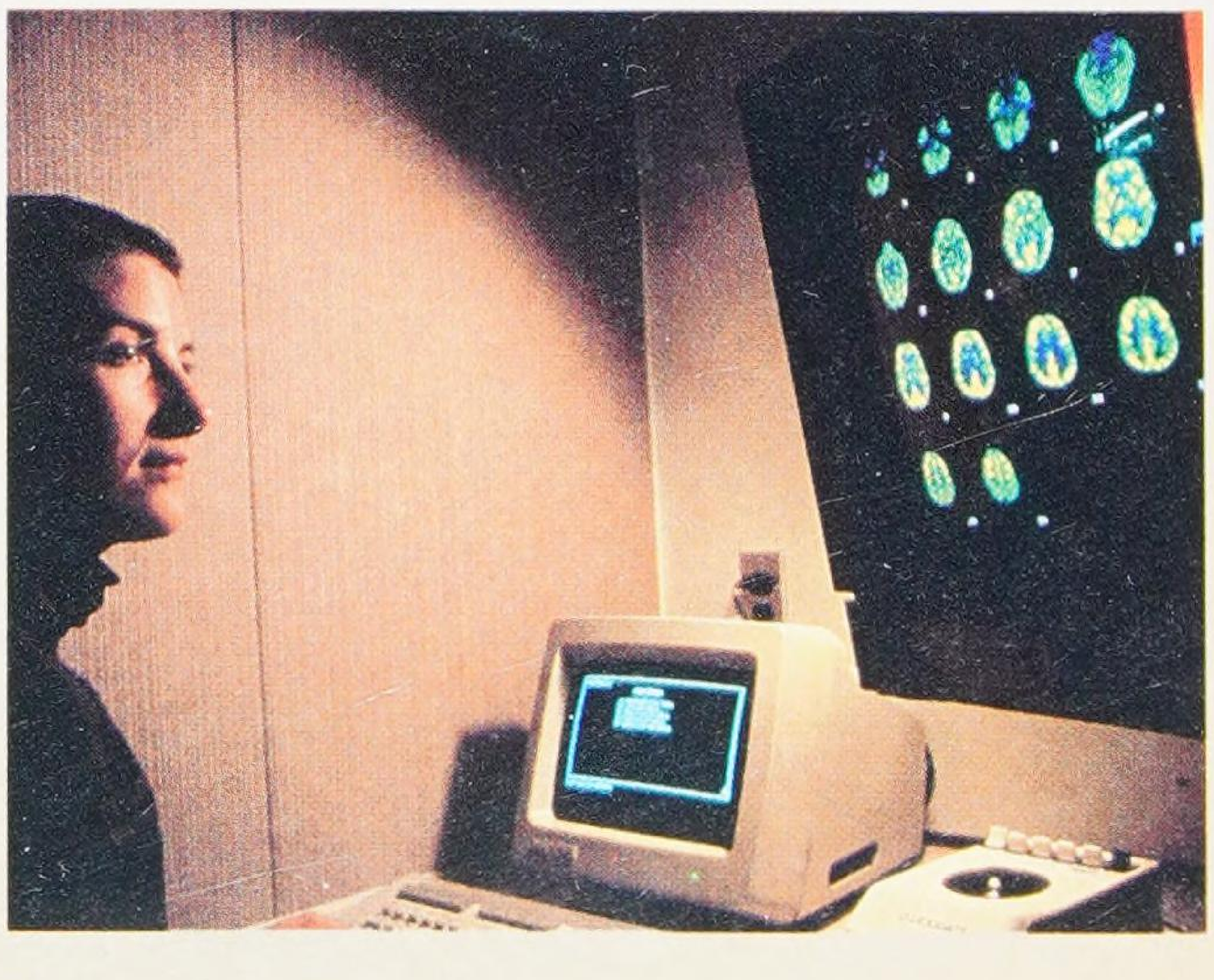
Figure 22-4. Different areas of the brain control specific body activities.

TECHNOLOGY

Watching the Brain at Work

Many medical centers in the United States are now using positron emission tomography (PET) for research and diagnosis of the brain. The simple sugar, glucose, is tagged with a radioactive tracer and fed to the patient. The tracer moves through the circulatory system of the brain and gives off particles called positrons. Positrons collide with electrons from the body and release a form of energy. The path of the energy appears as an image on a color monitor. The image shows where energy is used in different areas of the brain as these areas become stimulated.

Scientists can use PET to go beyond looking at just the physical makeup of the brain. By comparing PET images formed when people perform different tasks, researchers have pinpointed the areas of the brain used for seeing, reading, hearing, speaking, and thinking. **Think Critically:** How can PET help scientists understand what happens when someone has an epileptic seizure or when the brain processes language?



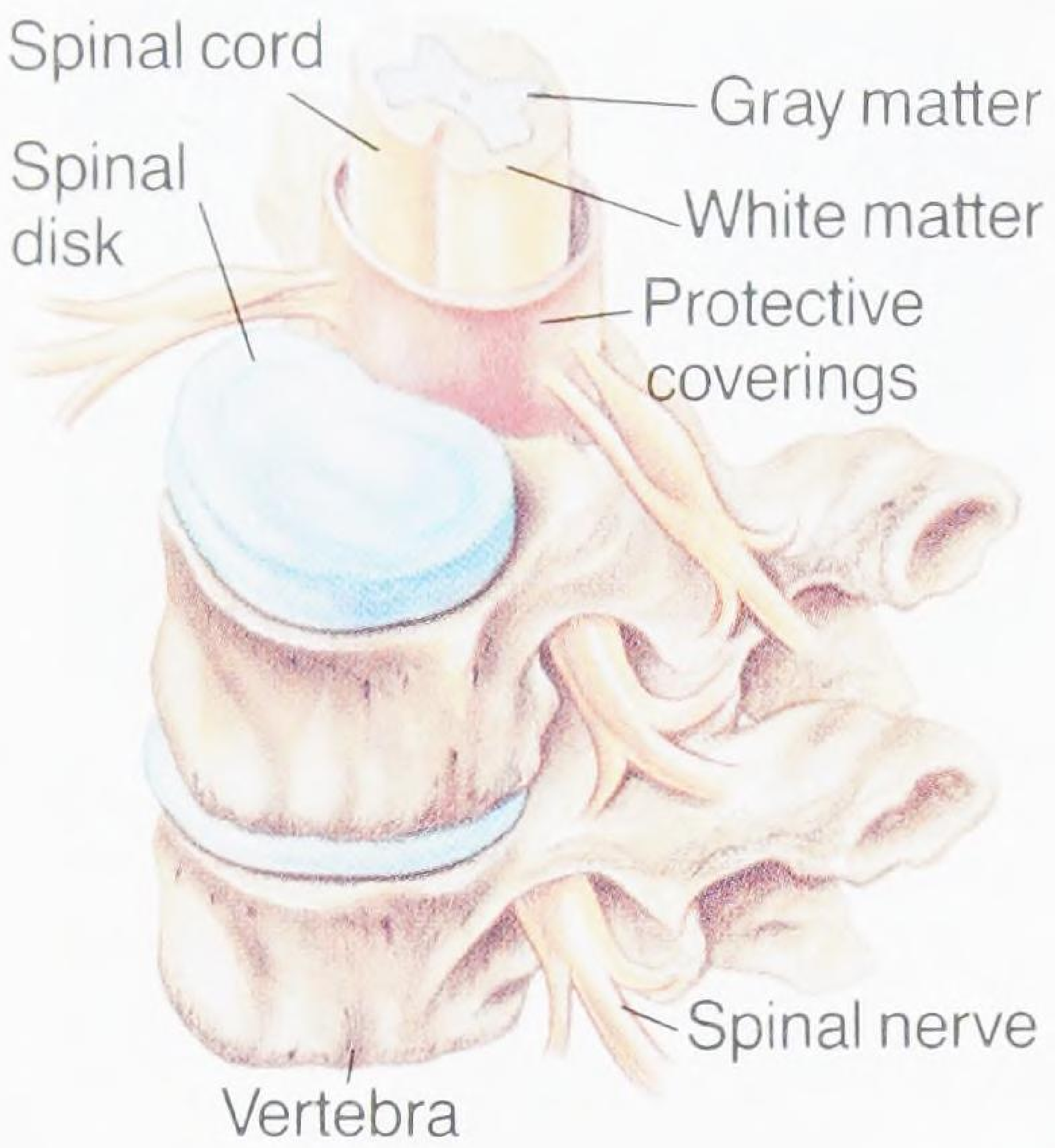


Figure 22-5. Impulses travel to and from the brain by way of the spinal cord.

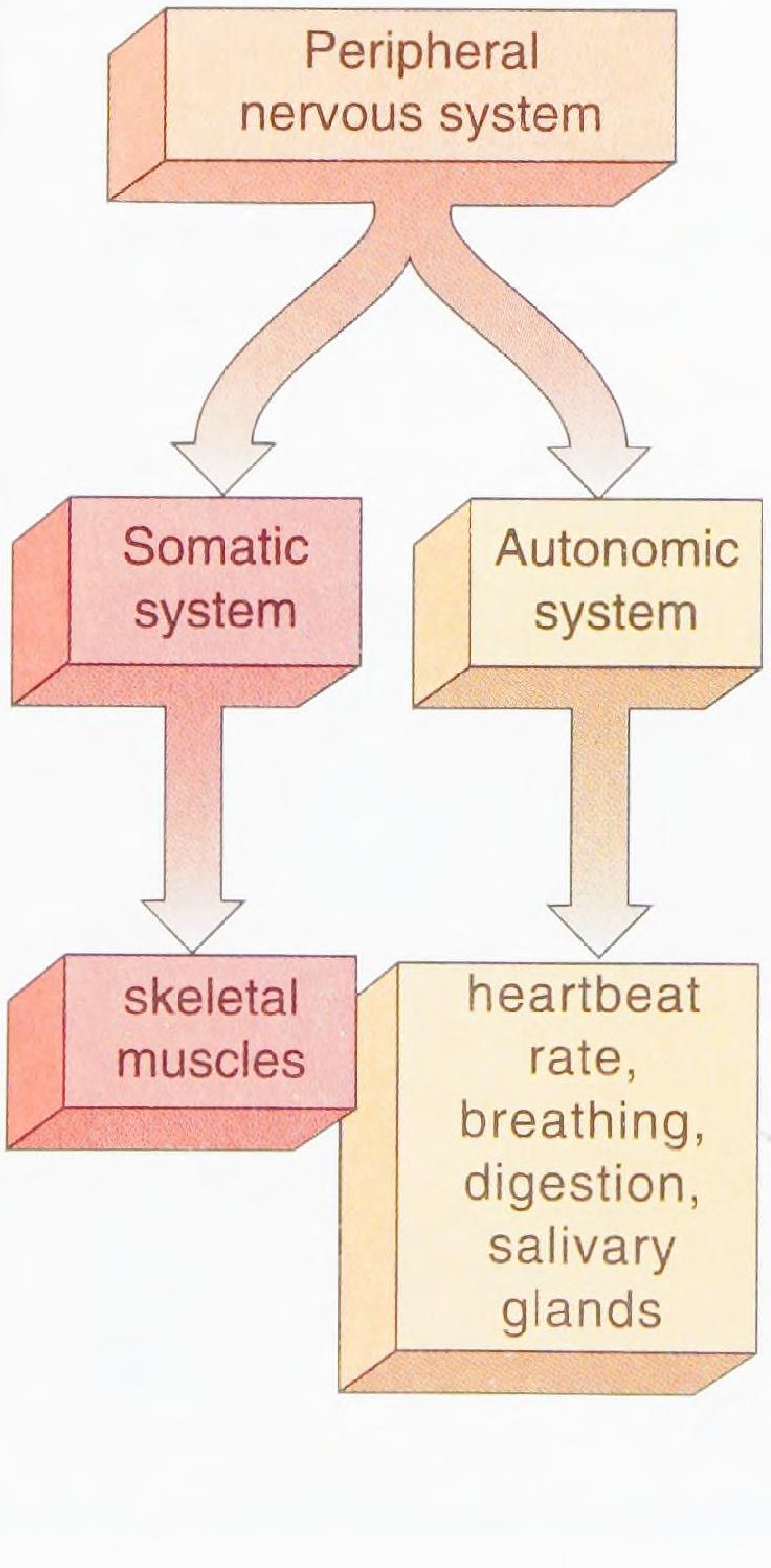
Your spinal cord is an extension of the brainstem. It is made up of bundles of neurons that carry impulses from all parts of the body to the brain and from the brain to all parts of your body. The spinal cord is about as big around as an adult thumb and 43 cm long. The CNS is protected by a bony cap called the skull, by vertebrae, and by three layers of membranes. Between some of these membranes is a fluid called cerebrospinal fluid. What purpose might this fluid serve?

The Peripheral Nervous System

Your brain and spinal cord are connected to the rest of your body by the peripheral nervous system. The PNS is made up of 12 pairs of cranial nerves from your brain and 31 pairs of spinal nerves from your spinal cord. These nerves link your central nervous system with all parts of your body. Spinal nerves are made up of bundles of sensory and motor neurons. For this reason, a single spinal nerve may have impulses going to and from the brain at the same time.

There are two divisions of the peripheral nervous system. The *somatic system* consists of the cranial and spinal nerves that go from the central nervous system to your skeletal muscles. The second division, the *autonomic system,* controls your heartbeat rate, breathing, digestion, and gland functions. When your salivary glands release saliva, your autonomic system is at work. Use Figure 22-6 to help you remember these two divisions.

Figure 22-6. The Divisions of the Peripheral Nervous System


Peripheral nervous system
Somatic system
Autonomic system
skeletal muscles
heartbeat rate, breathing, digestion, salivary glands

Reflexes

Have you ever jumped back from something hot or sharp? Then you've experienced a reflex. A **reflex** is an involuntary and automatic response to a stimulus. You can't control reflexes, but many times they have saved lives. A reflex involves a simple nerve pathway called a reflex arc. Figure 22-7 shows a reflex arc. As someone hands you a piece of pizza, some very hot cheese falls on your finger. Sensory receptors in your finger respond to the hot cheese, and an impulse is sent to the spinal cord. The impulse passes to an interneuron in the spinal cord that immediately relays the impulse to motor neurons. Motor neurons transmit the impulse to muscles in your arm. Instantly, without thinking, you pull your arm back in response to the burning food. This is a withdrawal

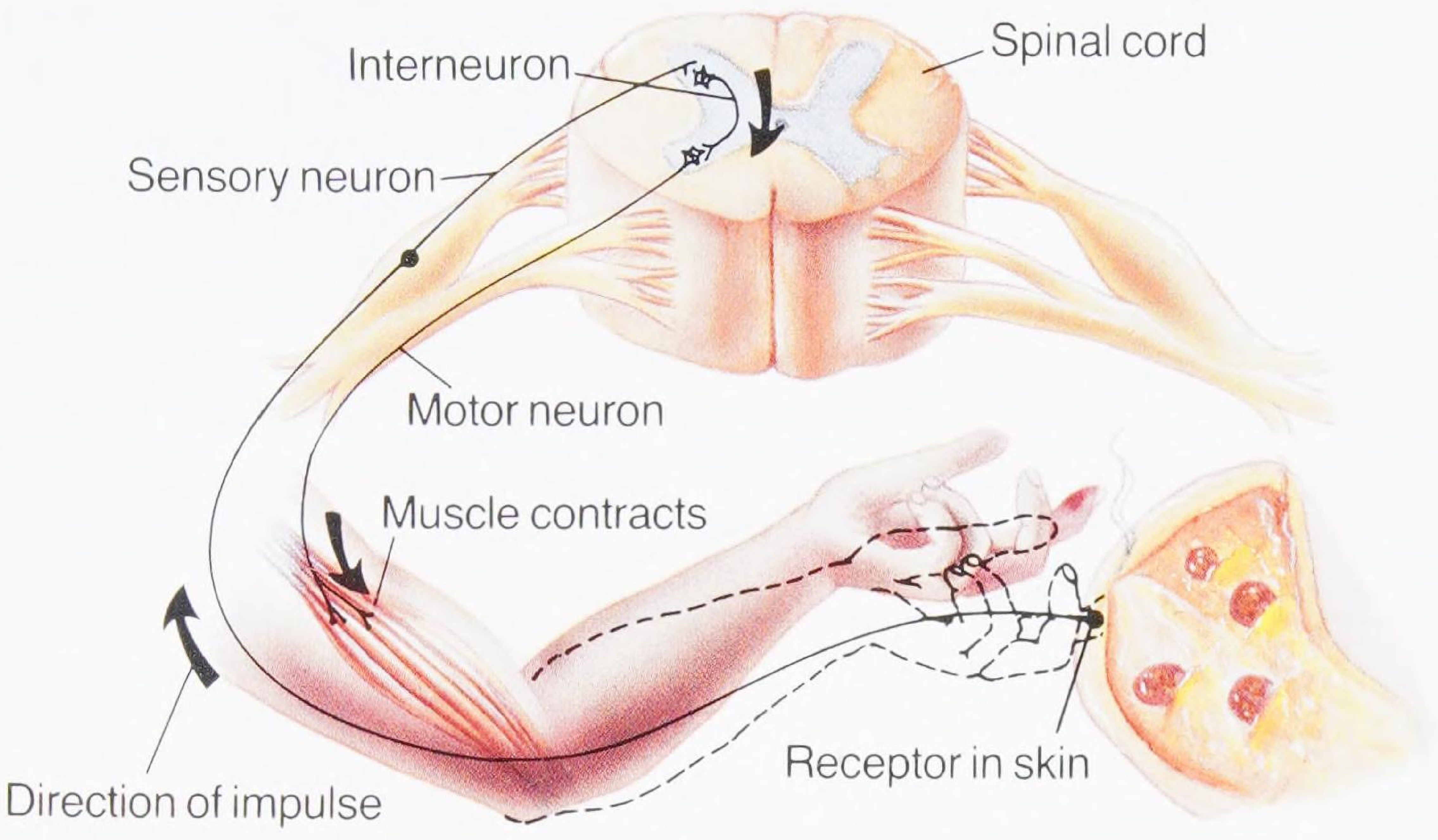


Figure 22-7. Your response in a reflex is controlled in your spinal cord, not in your brain.

reflex. A reflex allows the body to respond without having to think about what action to take. Reflex responses are controlled in your spinal cord, not in your brain. Your brain acts after the reflex to help you figure out what to do to make the pain stop.

Where are reflexes controlled?

Remember the rubber mask scare? What would have happened if your breathing and heartbeat rate didn't calm down within a few minutes? Your body system can't be kept in a state of continual excitement. The organs of your nervous system control and coordinate responses to maintain homeostasis within your body.

SECTION REVIEW

1. Draw and label the parts of a neuron.
2. Compare the central and peripheral nervous systems.
3. Explain what happens to an impulse at a synapse.
4. Compare sensory and motor neurons.
5. **Apply:** Describe the reflex pathway of nerve impulses when you step accidentally on a sharp object.
6. **Connect to Chemistry:** Find out what two chemical elements play roles in moving an impulse along an axon.

Concept Mapping

Skill Builder

Prepare a chain of events concept map of the different kinds of neurons an impulse moves along from the stimulus to a response. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

ACTIVITY 22-1

Reaction Time

Problem: *How can reaction time be measured?*

Materials

- penny
- meterstick

Procedure

Part A

1. Hold your right arm out with the palm down. Put a penny on the center of the back of your hand.
2. Tilt your hand so that the penny slides off. Try to catch the penny with your right hand.
3. Repeat Step 2 nine more times. In a table like the one shown, record how many times you catch the penny and how many times you drop the penny.
4. Repeat Steps 2 and 3 with your left hand. *Record* your results.

Part B

1. Have a partner hold a penny about 0.5 m above the palm of your hand.
2. When your partner drops the penny, move your hand before the penny hits it.
3. Repeat Step 2 for different distances. Record your results in the table.
4. Repeat Steps 2 and 3 with your other hand. *Record* your results.

Part C

1. Have a partner hold a metric ruler at one end so that the other end of the ruler is between your thumb and index finger.
2. Keep your eyes on the bottom of the ruler as your partner releases the ruler. Try to catch the ruler.
3. Repeat Step 2 nine more times.
4. Record the distance the ruler has fallen each time you catch it.
5. Repeat Steps 2 and 3 with your other hand. *Record* your results.

Data and Observations

Part A

	Right Hand		Left Hand	
Trial	Caught	Not caught	Caught	Not caught
1				
2				

Part B

Trial	Distance above hand	Hit	Not hit
1			
2			

Part C

Trial	Distance fallen	
	Right hand	Left hand
1		
2		

Analyze

1. What was the stimulus in each activity?
2. What was the response in each activity?
3. What was the variable in each activity?

Conclude and Apply

4. Did you catch the penny, avoid the penny, and catch the ruler faster with your writing hand?
5. How did your response time improve?
6. How can reaction time be measured?
7. *Draw a conclusion* about how practice *relates* to stimulus-response time.

The Senses

22-2

Objectives

- List the sensory receptors in each sense organ.
- Explain what type of stimulus each sense organ responds to and how.
- Explain the need for healthy senses.

New Science Words

retina
cochlea
olfactory cells
taste buds

In Touch with Your Environment

Many stories by science fiction writers talk about energy force fields around spaceships. When some form of energy tries to enter the ship's force field, the ship is put on alert. Your body has an alerting system as well, in the form of sense organs. Your senses enable you to see, hear, smell, taste, touch, and feel whatever comes into your personal territory. The energy that stimulates your sense organs may be in the form of light rays, heat, sound waves, chemicals, or pressure. Sense organs are adapted for capturing and transmitting these different forms of energy.

Vision

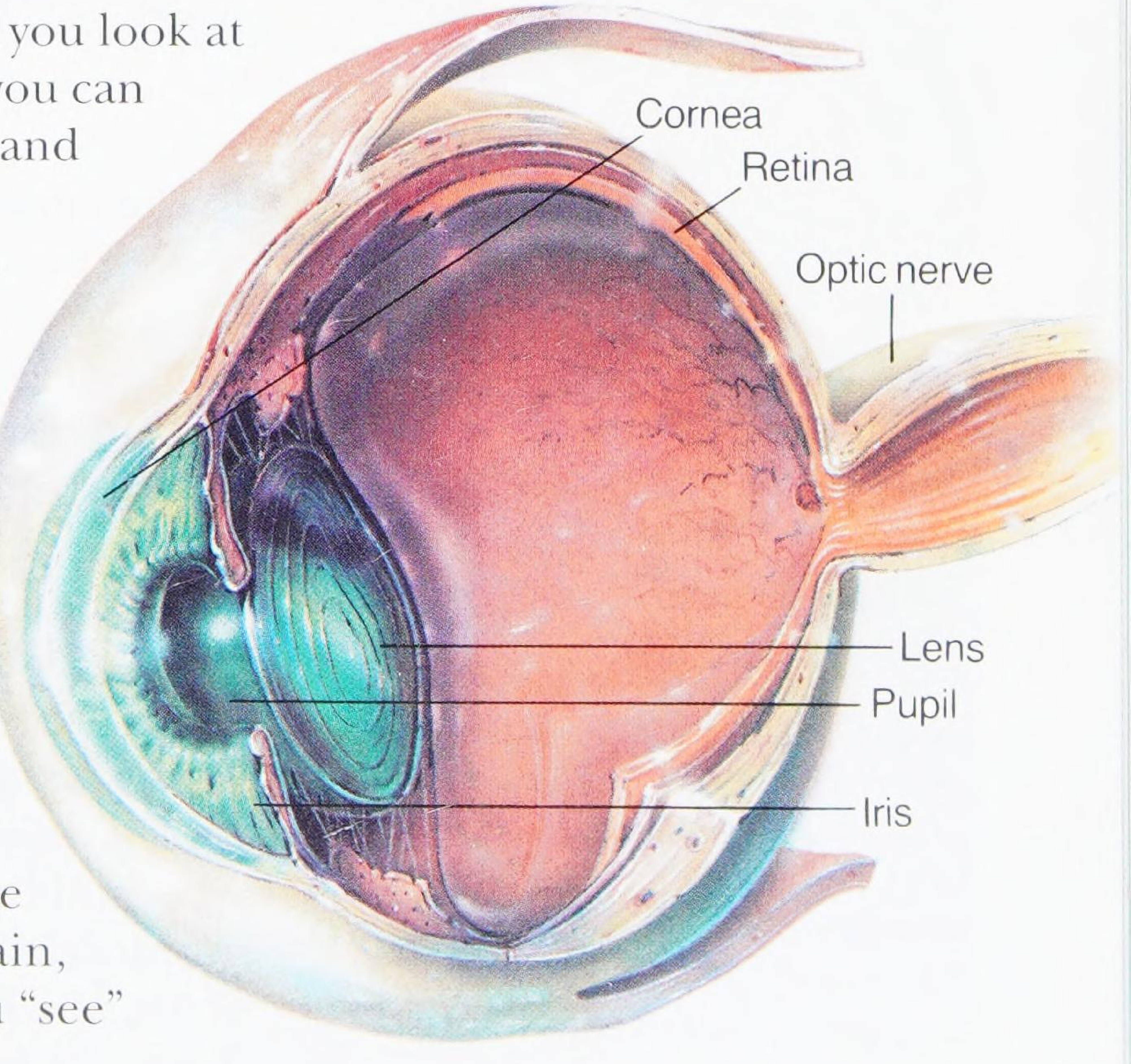
Think about the different kinds of things you look at every day. It's amazing that, all in one view, you can see words on a page, photographs in color, and a cat as it walks across the floor.

Light travels in a straight line unless something bends it. Your eyes are equipped with structures that bend light. Light rays are first bent by the cornea and then a lens. The lens directs the rays onto the retina (RET nuh). The **retina** is a tissue at the back of the eye that is sensitive to light energy. Rods and cones are cells in the retina. Cones respond to bright light and color. Rods respond to dim light. Light energy stimulates impulses in these cells. The impulses pass to the optic nerve, which carries them to the brain, where the impulses are interpreted and you "see" what you are looking at.

Connect to... Physics

Lenses in eyes are convex, but their shape can change over time. Find out what happens to the lens in a condition called *presbyopia*. What is the result?

Figure 22-8. The Parts of the Human Eye



Science and READING

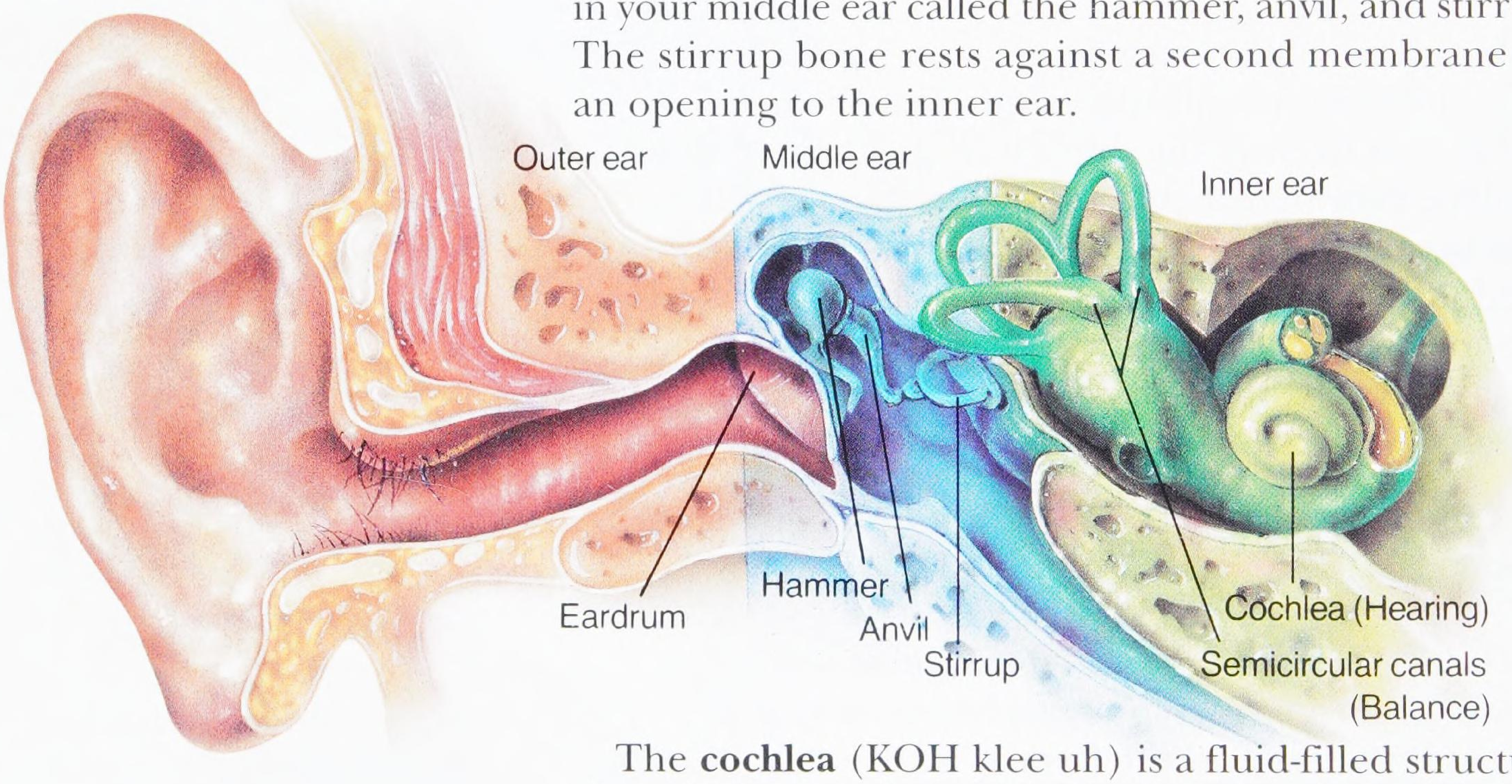
Find out how Helen Keller was able to learn to communicate even though she was deprived of sight and hearing at an early age.

Hearing

Sound energy is to hearing as light energy is to vision. When an object vibrates, it causes the air around it to also vibrate, thus producing energy in the form of sound waves. When sound waves reach your ears, they stimulate nerve cells deep in your ear. Impulses are sent to the brain. The brain responds, and you hear a sound.

Figure 22-9 shows that your ear is divided into three sections: the outer, middle, and inner ear. Your outer ear traps sound waves and funnels them down the ear canal to the middle ear. Once there, the sound waves cause the eardrum to vibrate much like the membrane on a drum. These vibrations then move through three little bones in your middle ear called the hammer, anvil, and stirrup. The stirrup bone rests against a second membrane on an opening to the inner ear.

Figure 22-9. Your ear responds to sound waves and to changes in the position of your head.



The **cochlea** (KOH klee uh) is a fluid-filled structure shaped like a snail's shell in the inner ear. When the stirrup vibrates, fluids in the cochlea also begin to vibrate. These vibrations stimulate nerve endings in the cochlea, and impulses are sent to the brain by the auditory nerve. Depending on how the nerve endings are stimulated, you hear a different type of sound. High-pitched sounds make the endings move differently from lower, deeper sounds. Sound produced by jet engines or rock instruments are as much as ten billion times greater than your ear is adapted to handle.

Balance is also controlled in the inner ear. Special structures and fluids in the inner ear constantly adjust to the position of your head. This stimulates impulses to the brain, which interprets the impulses and helps you make the necessary adjustments to maintain your balance.

MINI-Lab

How is balance maintained?

Draw two parallel vertical lines on the chalkboard and have a student stand between them, as still and straight as possible for three minutes. *Observe* how well balance is maintained. Next, have the student close his or her eyes and repeat standing within the lines for three more minutes. When was balance more difficult to be maintained? Suggest an explanation.

Smell

A bloodhound is able to track a particular scent through fields and forest. Our ability to detect odors is not as sharp, but our sense of smell is important for survival and enjoyment.

You can smell food because it gives off molecules into the air. Nasal passages contain sensitive nerve cells called **olfactory cells** that are stimulated by gas molecules. The cells are kept moist by mucous glands. When gas molecules in the air dissolve in this moisture, the cells become stimulated. If enough gas molecules are present, an impulse starts in these cells and travels to the brain.

The brain interprets the stimulus. If it is recognized from previous experience, you can identify the odor. If you can't recognize a particular odor, it is remembered and can be identified the next time, especially if it's a bad one. Certain odors even let you recall events from your childhood.

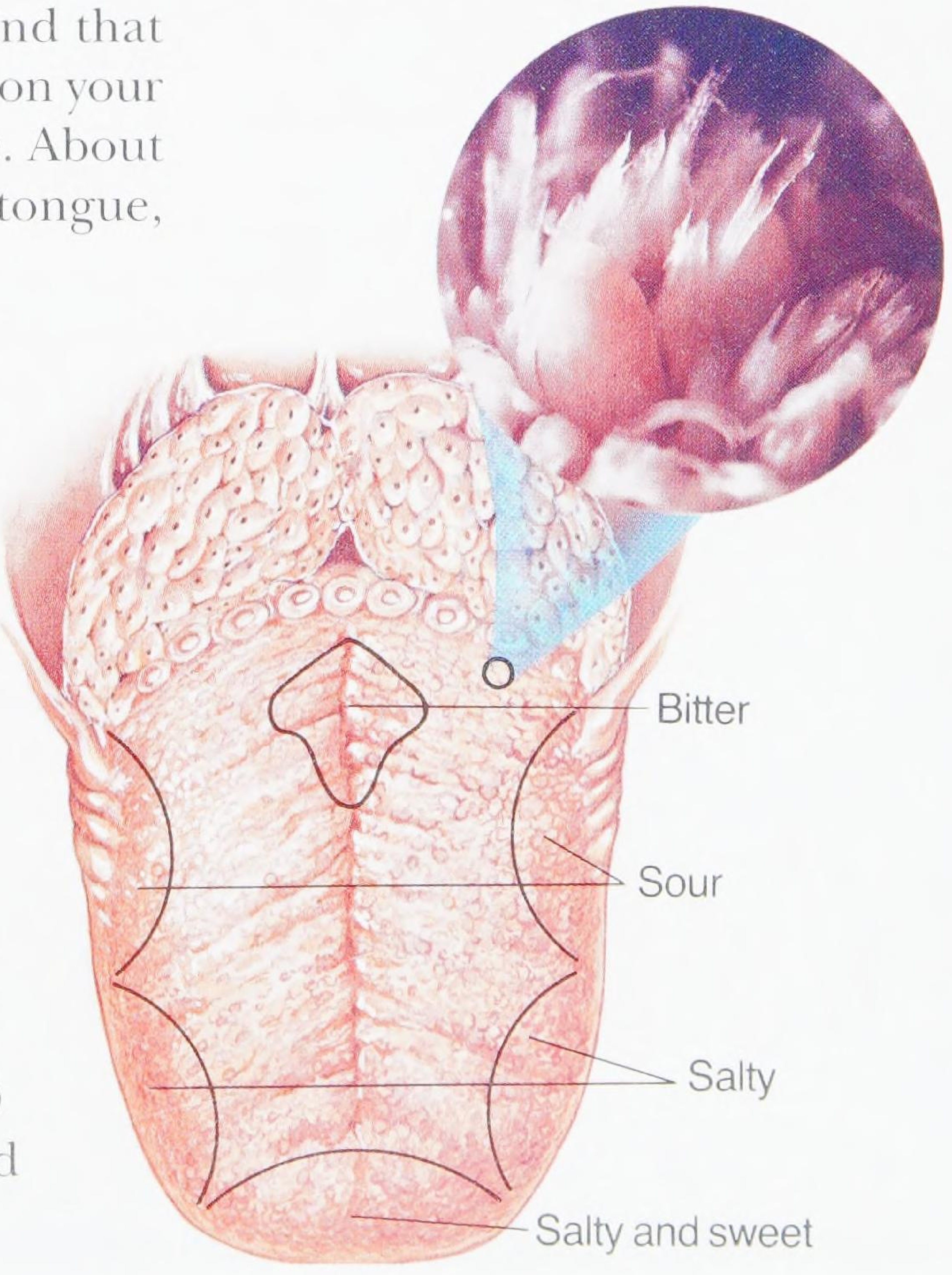
Taste

Have you ever tasted a new food or medicine with the tip of your tongue and found that it tasted sweet? Then you may have been unpleasantly surprised to find that when you swallowed it, it tasted bitter. **Taste buds** on your tongue are the major sensory receptors for taste. About ten thousand taste buds are found all over your tongue, enabling you to tell one taste from another.

Taste buds respond to chemical stimuli. When you think of food, your mouth begins to water with saliva. This adaptation is helpful because in order to taste something, it has to be dissolved in water. Saliva in your mouth dissolves food. The solution washes over the taste buds, and an impulse is started that is sent to your brain. The brain interprets the impulse and enables you to tell what you are tasting.

Taste buds respond to more than one taste sensation. However, there are areas of the tongue that seem to respond to one taste more easily than another. There are four basic taste sensations: sweet, salty, sour, and bitter. Figure 22-10 shows where these tastes are commonly stimulated on your tongue.

Figure 22-10. Taste buds contain nerve endings that react to chemicals in food.



Smell and taste are related. When you have a head cold with a stuffy nose, food seems tasteless because it is blocked from contacting the moist membranes in your nasal passages. On the other hand, hot food is often smelled when odor molecules from food in your mouth come in contact with the membranes.

Touch, Pressure, Pain, and Temperature

How important is it to be able to feel pain inside your body? Sensory receptors in your internal organs, as well as throughout your skin, respond to touch, pressure, pain, and temperature. These receptors pick up changes in touch, pressure, and temperature and transmit impulses to the brain or spinal cord. The body responds in such a way to protect itself or maintain homeostasis.

Your fingertips have many different types of receptors for touch. As a result, you can tell whether an object is rough or smooth, hot or cold, light or heavy. Your lips are sensitive to heat and prevent you from drinking something so hot that it would burn you. Pressure sensitive cells in the dermis give warning of danger to a body part and enable you to move to avoid injury.

Your senses are adaptations that help you enjoy or avoid things around you. Through your senses you constantly make small and large adjustments to your environment.

Did You Know?

Referred pain is pain started in an internal organ but felt elsewhere in the body. Pain from an inflamed gallbladder may be felt on the right side of the neck, under the right shoulder blade, and at the diaphragm.

SECTION REVIEW

1. What is the retina and how is it stimulated?
2. How do sound waves affect different parts of the ear?
3. How are smell and taste related?
4. Why is it important to have receptors for pain and pressure in your internal organs as well as in your skin?
5. **Apply:** What sensory receptors are involved when you accidentally close your hand in a door?
6. **Connect to Physics:** Find out the function of tiny calcium carbonate stones called otoliths in your inner ears.

Skill Builder

Making and Using Tables

Organize the information on senses in a table that names the sense organs and gives the type of energy to which they respond. If you need help, refer to Making and Using Tables in the **Skill Handbook** on page 690.

DESIGNING AN EXPERIMENT

ACTIVITY 22-2

Investigating Skin Sensitivity

Your body responds to touch, pressure, and temperature. Sensory receptors in your skin allow you to know what is happening around you. Certain areas of the skin are more sensitive than others. These sensitivities can be for protection or to maintain homeostasis. In this activity, you will find out which areas of your skin are more sensitive than others.

Getting Started

In preparation for designing your experiment, answer the following questions:

1. What question are you investigating?
2. How are you going to test skin sensitivity?
3. What variables are in this experiment?

Safety Notes

Be careful if you use sharp objects. Do not apply heavy pressure when using your testing device.

Hypothesis

What is your **hypothesis**? What is the reasoning behind your hypothesis? Share this information with your group. Choose the best idea that can be investigated in the classroom and decide on a group hypothesis.

Brainstorm

Working in a group, select five areas on the body to test, such as fingertips or the back of the neck. *Predict* which areas are most sensitive to touch. Rank the areas from 5 (the most sensitive) to 1 (the least sensitive). Devise a data table and record your predictions in it.

Experimental Plan

- Design your experiment to test one variable. Make a plan to collect quantitative data.
- In a numbered list, similar to a recipe, make a set of directions that anyone can follow to do the experiment.
- Make a list of needed materials that you would use to determine which areas of the skin are more sensitive.

Answer the Following Questions

1. What will you measure?
2. How many areas will you test?
3. Is your data table ready to use?

Make sure your teacher has approved your experimental plan before you go further.

Data and Observations

Carry out your experiment and use the data table to record your observations.

Data Analysis and Interpretation

1. On what area of the body tested can you distinguish the closest stimuli?
2. What area tested was least sensitive to close stimuli?
3. *Compare* your test results with your prediction.
4. What structures in the dermis provide a sense of touch?
5. Which areas tested were more sensitive to touch?
6. What do your test results indicate about the distribution of touch receptors in the skin?

Going Further

1. Discuss the advantages of some areas of the body being more sensitive to sharp objects than others.
2. Prepare an outline of an investigation to determine if there are areas of the skin that are more sensitive to cold.

SCIENCE & SOCIETY

22-3 Alzheimer's Disease

New Science Words

Alzheimer's disease

Objectives

- Describe Alzheimer's disease.
- State some of the results of Alzheimer's disease on society.
- Explain two possible causes of Alzheimer's.

What Is Alzheimer's Disease?

Alzheimer's disease is the failure of nerve cells in the brain to communicate with each other. Researchers are attempting to determine what causes this breakdown. They have found that Alzheimer's patients have unusually low amounts of the enzyme that signals the cell to produce a nerve-transmitting chemical called acetylcholine. Without this chemical, nerve impulses aren't carried from one neuron to the next. It has also been found that the brains of Alzheimer's patients use far less oxygen than normal. Autopsies of Alzheimer's patients show that many neurons have died. The destruction of brain cells caused by Alzheimer's disease results in such severe memory loss that, over a period of years, the victim becomes a very different person. At first, patients forget simple things. Items are misplaced around the house. Later, they may not recognize family members or even know who they are. Eventually, after losing physical functioning, they die. What causes this condition?

Figure 22-11. Support groups help people who have the responsibility for caring for people with Alzheimer's disease.

Researchers are still working to determine the cause of Alzheimer's. One idea is that the disease may be inherited. Some researchers believe that a defect exists on chromosome 19. Children of Alzheimer's victims show a greater chance of developing the disease than others. Other evidence, however, shows that a protein called amyloid B, which helps cell growth in young brain cells, has the opposite effect in older people. There is also evidence that young people who have experimented with so-called designer drugs have developed a form of Alzheimer's disease.

The Cost of Disease

It is believed that about 100 000 people die with Alzheimer's disease in the United States every year. The cost of this disease to families and society is very high. Home health care for a patient ranges from \$18 000 to \$20 000 a year. In a skilled care nursing home, the cost averages about \$25 000 per year. In 1985, it was estimated that Alzheimer's disease and similar disorders involving loss of brain function cost the United States about \$88 billion. None of these people can be cured.

There are other costs as well. The stress involved in caring for someone with Alzheimer's disease can be damaging in itself. Studies show that the extreme stress harms caregivers' immune systems and can make them more susceptible to illness.

In Your JOURNAL

Find out what Medicare is. **In your Journal,** write a one-page description of this health plan. Include in your report how a person qualifies for Medicare benefits.

Is a cure for Alzheimer's in sight? Because intensive research has been conducted for only about a decade, little progress has been made. Drugs that help produce more acetylcholine have been developed and tried. However, these were found to have severe side effects. Until scientists are able to find the cause of Alzheimer's disease, it will be difficult to find a cure.

What is Alzheimer's disease?

SECTION REVIEW

1. What happens to the brain of an Alzheimer's patient that causes memory loss?
2. What is the cost of this disease for society? How might society benefit from what is learned about Alzheimer's disease?
3. What are two possible causes of Alzheimer's?

You Decide!

SCIENCE & SOCIETY

It can be very difficult to care for a family member who has Alzheimer's disease. Due to loss of memory, the patient needs constant care. Would you be able to help take care of such a family member in your home? What might be the advantages and disadvantages of letting the person stay in a nursing care facility instead?

22-4 Your Endocrine System

New Science Words

hormones
target tissues

Objectives

- Explain the function of hormones.
- Name three endocrine glands and explain the effects of their hormones.
- Explain how a feedback system works.

Connect to... Chemistry

The pituitary gland has been called the "master gland" because it controls so many other endocrine glands in the body. Find out how the pituitary affects the kidneys and bladder, and growth.

Endocrine System

"The tallest man in the world!" and "the shortest woman in the land!" were commonly seen entertainers in circuses of the past. These people were ordinary persons except for their extraordinary height or lack of height. In most cases, their sizes were the result of a malfunction in their endocrine (EN duh krun) systems.

The endocrine system consists of ductless glands throughout the body. Your salivary glands and your liver are glands that produce substances that flow through ducts. Endocrine glands, however, have no ducts. Their secretions move directly from the cells of the gland into your bloodstream. Endocrine secretions, called **hormones,** usually control activities in parts of the body other than right around the gland. Hormones affect specific tissues called **target tissues.** Target tissues are frequently in another part of the body at a distance from the gland that affects them. Table 22-1 shows the position of eight endocrine glands, the hormones they produce, and their target tissues.

In Chapter 19, the pancreas was described for its role in producing a digestive enzyme. However, other groups of cells in the pancreas also secrete hormones. One of these hormones, insulin (IN suh lin), enables cells to take in glucose. Glucose is the main source of energy for respiration in cells. Normally, insulin enables glucose to pass from the bloodstream through cell membranes. Persons who can't make insulin are diabetic. That means that insulin isn't there to enable glucose to get into cells.

Figure 22-12. Some athletes are extremely tall as a result of excess growth hormone.

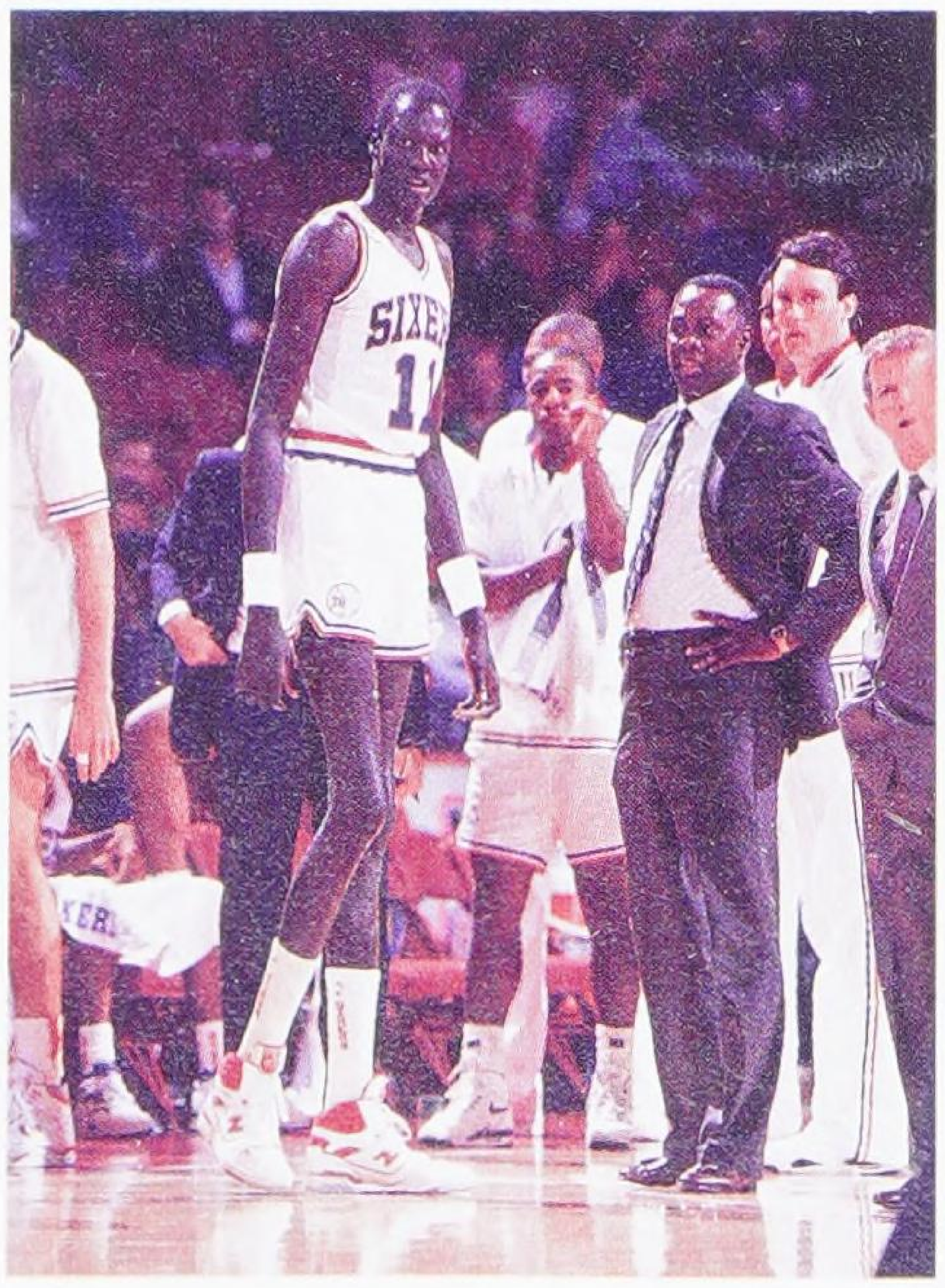
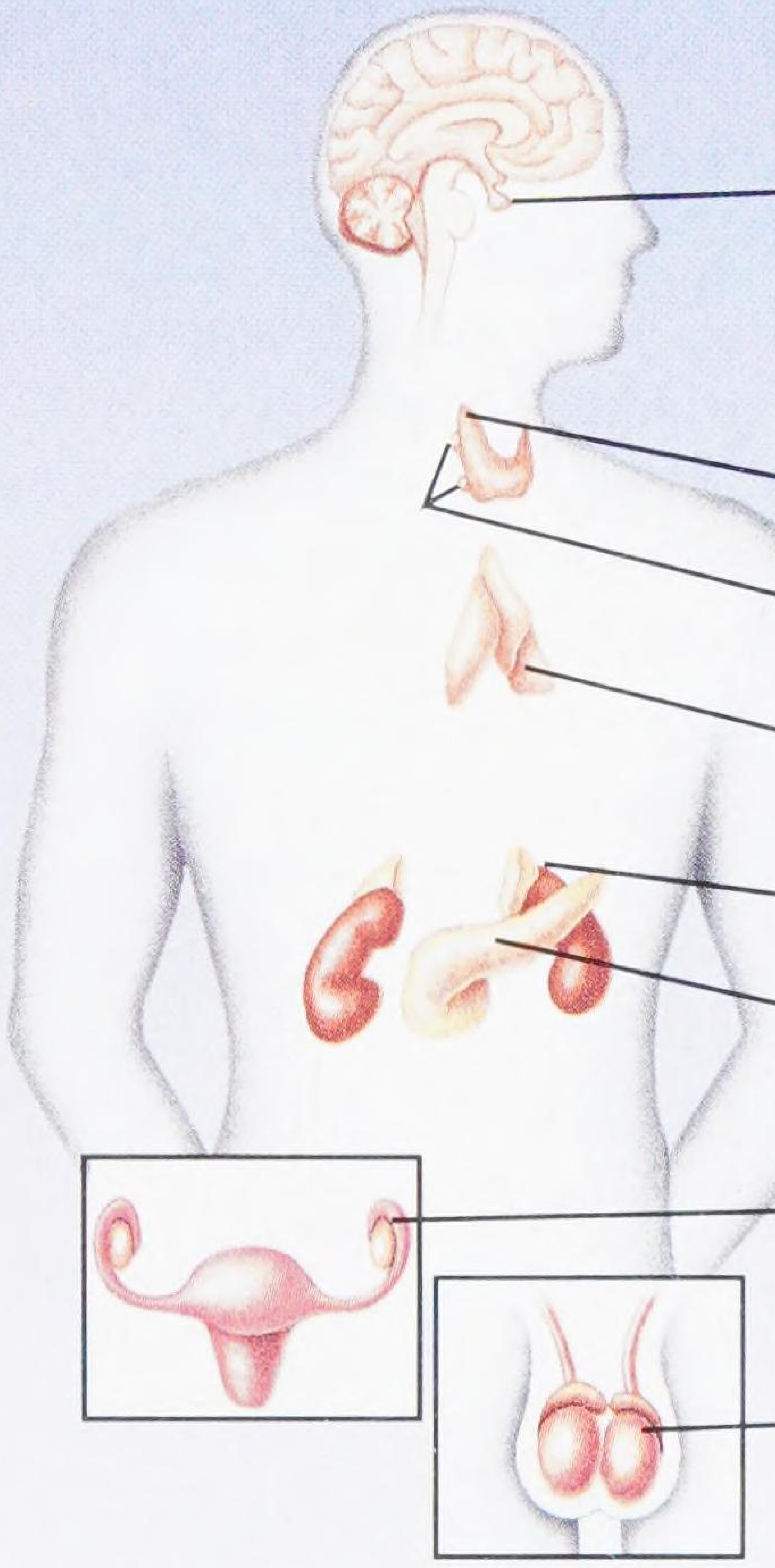


Table 22-1

ENDOCRINE GLANDS

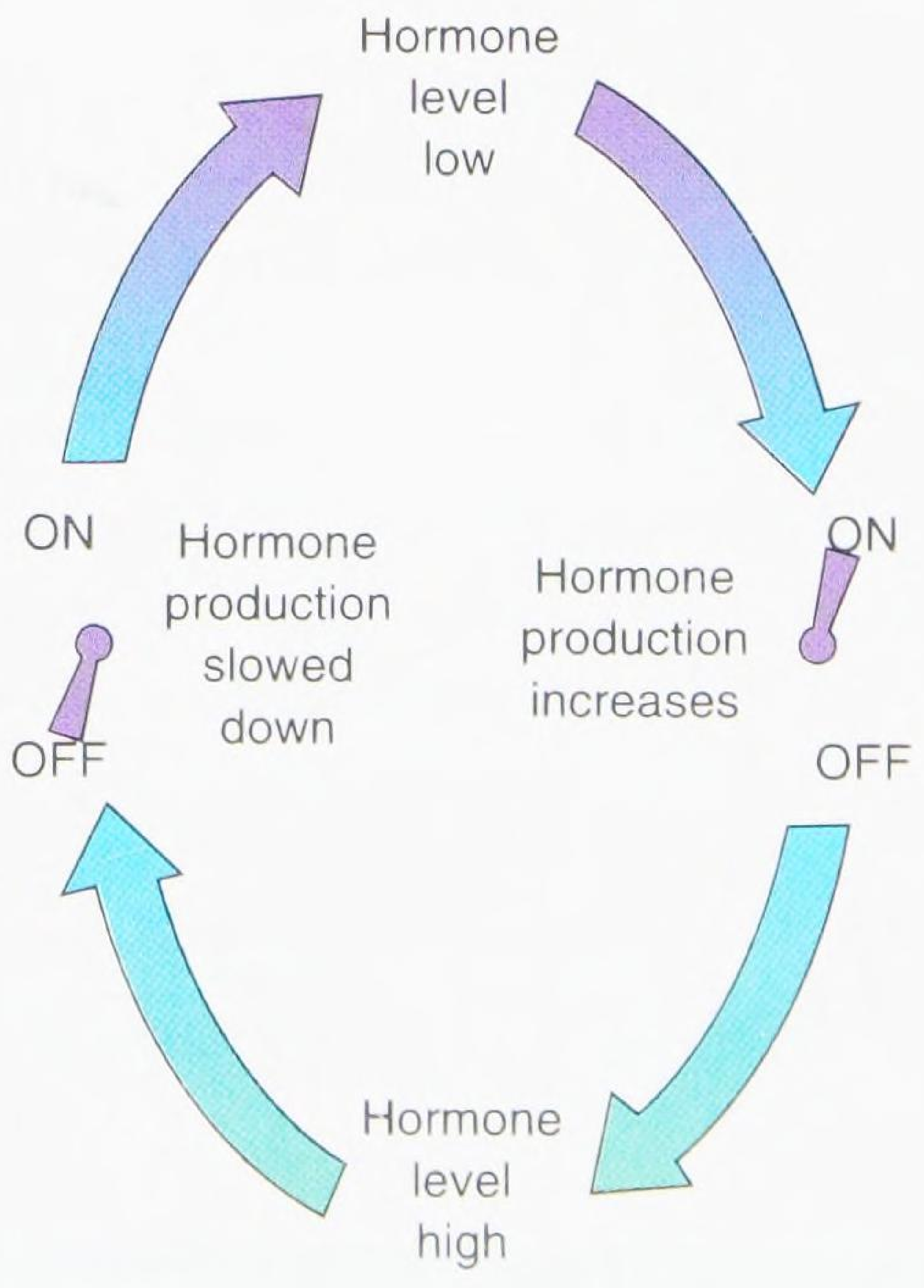


Gland	Regulates
Pituitary	Enables other endocrine glands to produce hormones Milk production Growth
Thyroid	Carbohydrate use
Parathyroids	Calcium
Thymus	Parts of immune system
Adrenal	Blood sugar; metabolism
Pancreas	Blood sugar
Ovaries	Production of eggs; development of sex organs in females
Testes	Production of sperm; development of sex organs in males

The reproductive glands also produce hormones. The functions of the hormones of the ovaries and testes will be discussed in Chapter 23.

A Negative Feedback System

To control the amount of hormone an endocrine gland produces, the endocrine system sends chemical information back and forth to itself. This is a negative feedback system. It works much the way a thermostat works. When the temperature in a room drops below a certain level, a thermostat signals the furnace to turn on. Once the furnace has raised the temperature to the level set on the thermostat, the furnace shuts off. It will stay off until the thermostat signals again. Once a target tissue responds to its hormone, the tissue sends a chemical signal back to the gland. This signal causes the gland to stop or slow down production. When the level of the hormone in the bloodstream drops again, the endocrine gland is signaled to start the secretion of the hormone again. In this way, the concentration of the hormone in the bloodstream is kept at the needed level, and homeostasis is maintained.



PROBLEM SOLVING

Why am I so tired?

Carrie hasn't been feeling well lately. She complains about feeling tired all the time.

"She just doesn't have any get-up-and-go," her mother told the doctor. The doctor ordered some blood tests and questioned Carrie about her diet. After school one afternoon, Carrie went to the doctor's office to hear the results of the tests. The tests showed that her blood sugar was much too high. The doctor gave her strict instructions to follow detailing what she was allowed to eat every day. He told Carrie that she showed signs of diabetes. What endocrine gland is involved in diabetes?

Think Critically: How could Carrie be tired all the time and yet have a high blood sugar reading?

Hormones secreted by endocrine glands go directly into the bloodstream and affect target tissues. The level of the hormone is controlled by a negative feedback system. In this way, many chemicals in the blood and many body functions are controlled.

SECTION REVIEW

1. What is the function of a hormone?
2. What is a negative feedback system?
3. Explain how three hormones work in the body.
4. **Apply:** How would a lack of insulin affect respiration in a person's cells?
5. **Connect to Chemistry:** Find out why people in most areas need to use iodized salt.

Skill Builder

Comparing and Contrasting

In what ways are the nervous system and endocrine system alike? If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.

CHAPTER REVIEW

SUMMARY

22-1: Your Nervous System

1. A neuron is the basic unit of structure and function of the nervous system.

2. A stimulus is detected by sensory neurons. Impulses are carried to the interneurons where the proper response is determined and transmitted to the motor neurons. A response is made automatically; this is a reflex.

3. The central nervous system contains the brain and spinal cord. The peripheral nervous system is composed of cranial and spinal nerves.

22-2: The Senses

1. The eyes respond to light energy, and the ears respond to sound waves. Interpretation of the stimuli is done by the cerebrum.

2. Olfactory cells of the nose and taste buds of the tongue are stimulated by chemicals. This stimulation produces impulses that are interpreted as different tastes.

22-3: Science and Society: Alzheimer's Disease

1. Neural transmitters carry impulses across synapses between neurons.

2. In Alzheimer's disease, neural transmission is impaired, resulting in memory loss and physical disfunctioning.

3. Scientists think a virus, chemical imbalance, or heredity are possible causes of Alzheimer's disease.

22-4: Your Endocrine System

1. Endocrine glands secrete hormones directly into the bloodstream.

2. Hormones affect specific tissues throughout the body.

3. A change in the body causes a gland to function. Once homeostasis is reached, the gland receives a signal to slow or stop its secretion.

KEY SCIENCE WORDS

a. **Alzheimer's disease**
b. **axon**
c. **brainstem**
d. **central nervous system**
e. **cerebellum**
f. **cerebrum**
g. **cochlea**
h. **dendrites**
i. **hormones**
j. **interneurons**
k. **motor neurons**
l. **neuron**
m. **olfactory cells**
n. **peripheral nervous system**
o. **reflex**
p. **retina**
q. **sensory neurons**
r. **synapse**
s. **target tissues**
t. **taste buds**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. neurons carrying impulses from the brain
2. basic unit of nervous system
3. nerve cells between sensory and motor neurons
4. gap between neurons
5. division containing brain and spinal cord
6. an automatic response to stimuli
7. light-sensitive tissue of the eye
8. center for coordination of voluntary muscle action
9. inner ear structure containing fluid
10. nerve cells that respond to gas molecules

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. Impulses cross synapses by way of _______.
a. osmosis **c.** a cell body
b. interneurons **d.** a chemical

2. The neuron structures that carry impulses to the cell body are _______.
a. axons **c.** synapses
b. dendrites **d.** nucleus

3. Neurons detecting stimuli in the skin and eyes are _______.
a. interneurons **c.** sensory neurons
b. motor neurons **d.** synapses

4. The _______ is the largest part of the brain.
a. cerebellum **c.** cerebrum
b. brainstem **d.** pons

5. The _______ controls voluntary muscle.
a. cerebellum **c.** cerebrum
b. brainstem **d.** pons

6. The ______ is the part of the brain that is divided into two hemispheres.
a. cerebellum **c.** cerebrum
b. brainstem **d.** spinal cord

7. The _______ is (are) controlled by the somatic division of the PNS.
a. skeletal muscles **c.** glands
b. heart **d.** salivary glands

8. The inner ear contains the _______.
a. anvil **c.** eardrum
b. hammer **d.** cochlea

9. The ______ gland controls many other endocrine glands throughout the body.
a. adrenal **c.** pituitary
b. thyroid **d.** pancreas

10. Ductless glands produce _______.
a. enzymes **c.** hormones
b. target tissues **d.** saliva

USING LAB SKILLS

11. The MINI-Lab on page 508 compared the sense of smell in males and females. Repeat this experiment to test differences in ability to smell between children and adults. Are there differences in their ability to detect odors?

12. The Activity on page 519 focused on skin sensitivity on the upper body. Try this activity on the lower part of the leg and on the foot. What did you find out about the distribution there?

THINK AND WRITE CRITICALLY

Answer the following problems in your Journal using complete sentences.

13. Discuss why taste and smell are protective.

14. What would happen if a chemical was blocking many synapses?

15. List the effects adrenal gland hormones would have on your body as you prepare to run a race.

APPLY

16. Why is it helpful to have impulses move in only one direction in a neuron?
17. How are reflexes protective?
18. How is your endocrine system like the thermostat in a house?
19. Describe an example of a problem that results from improper gland functioning.
20. If a fly were to land on your face and on your back, which might you feel first? Explain how you would test your choice.

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Classifying:** Classify the types of neurons as to their location and direction of impulse.
2. **Comparing and Contrasting:** Compare and contrast the structures and functions of the cerebrum, cerebellum, and brainstem. Include in your discussion the following functions: balance, homeostasis, involuntary muscles, muscle tone, memory, voluntary muscles, thinking, senses.
3. **Sequencing:** Sequence the structures through which light passes in the eye.
4. **Interpreting Scientific Illustrations:** Using the diagram of the synapse on page 510, explain how an impulse moves from one neuron to another.
5. **Observing and Inferring:** If an impulse traveled down one neuron, but failed to move on to the next neuron, what might you infer about the first neuron?

PROJECTS

1. Work in Paired Partners to find out how Annie Sullivan communicated with Helen Keller by drawing letters in her hand. Obtain Braille books and Braille writing tools. Learn how these instruments are used.
2. Find out how hearing aids work. Explain why not all hearing-impaired persons can use hearing aids.

CHAPTER

23 Reproduction and Growth

You may have heard a newspaper or television story about a large family that has all girls or all boys. What do you think are the odds of a family having all boys or all girls? What do you think is the proportion of boys to girls among children born in the general population?

FIND OUT!

Do this simple activity to find out what proportion of newborns are boys and what proportion are girls.

Take a penny and toss it in the air. There is an equal chance that it will land heads or tails. Toss the penny a hundred times and keep a record of the times it falls heads up and the number of times it falls tails up. Keep a record of the order in which the penny landed. What did your record show? Did you sometimes have five or more heads before a tails fell? What application can you make to families who have five girls or five boys? *Infer* the chances that a girl would be born if there were a sixth child.

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 23-1 Human Reproduction
- The Reproductive System
- The Menstrual Cycle

Section 23-2 Fertilization to Birth
- Fertilization
- The Stages of the Embryo and Fetus
- Multiple Births

Section 23-3 Development after Birth
- Childbirth
- Infancy and Childhood
- Adolescence
- Adulthood

Section 23-4 Science and Society Aging
- Prolonging Life

Previewing Science Skills

- In the **Skill Builders,** you will sequence, graph, and outline data.
- In the **Activities,** you will interpret and graph data.
- In the **MINI-Labs,** you will interpret data and do research.

What's next?

In this chapter, you will find out that the chances of a boy or girl being conceived are equal. You will learn about the structures and function of the male and female reproductive systems. You will also learn about the development of a human from fertilization to old age.

23-1 Human Reproduction

New Science Words

testes
sperm
semen
ovaries
ovulation
uterus
vagina
menstrual cycle
menstruation
menopause

Objectives

- Explain the function of the reproductive system.
- Identify the major structures of the male reproductive system.
- Describe the functions of the major female reproductive organs.
- Explain the stages of the menstrual cycle.

The Reproductive System

Reproduction is the process that continues life on Earth. Human and all other sexually reproducing organisms form eggs and sperm to carry genetic information from one generation to the next. If you have ever babysat, you know that babies and young children require nearly constant attention. Mammals, including humans, produce few offspring at one time compared to invertebrate animals. Some tropical termite queens can lay 80 000 eggs a day for nearly 30 years! Can you imagine babysitting for that many offspring? Unlike many other animals, mammals must provide care for their offspring to ensure their survival.

In previous chapters, you have read that most human body systems are alike in males and females. This is not the case for the reproductive system. Males and females each have structures specialized for their role in reproduction.

The Male Reproductive System

Figure 23-1 shows the structures of the male reproductive system. The external organs of the male reproductive system are the penis and scrotum (SKROH tum). The penis is the male organ for reproduction and urination. Behind the penis is a saclike pouch called the scrotum that holds the testes. During puberty, the two **testes** begin to produce **sperm,** the male reproductive cells. Sperm are single cells with a head and tail. The tail moves the sperm, and the head contains genetic information. The scrotum helps regulate temperature for sperm production. It holds the testes outside the male's body. As a result, the testes have a lower temperature. This cooler temperature is necessary to produce sperm.

Connect to...

Physics

Shapes of objects are often related to their function. *Infer* why sperm have a streamlined head and an active tail.

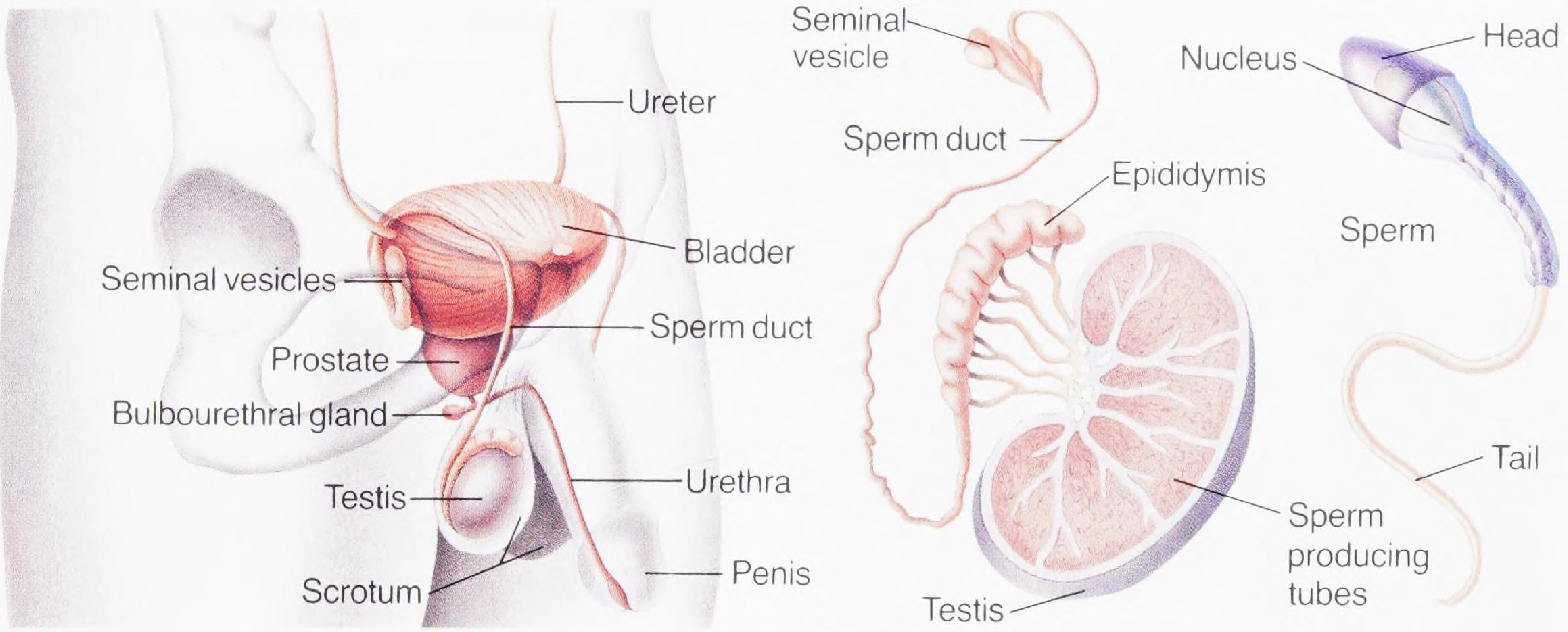


Figure 23-1. The structures of the male reproductive system are shown with a close-up of a testis and sperm.

Many organs help in the production, transport, and storage of sperm inside the male body. After sperm are produced, they travel from the testes through tubes that circle the bladder. Behind the bladder, a gland called the seminal vesicle provides sperm with a fluid that gives them energy and helps them move. This mixture of sperm and fluid is called **semen.** Semen leaves the body through the urethra, the same tube that carries urine from the body. Semen and urine never mix. A muscle at the back of the bladder contracts to prevent urine from entering the urethra as sperm are ejected from the body.

The Female Reproductive System

When a female begins puberty, the female sex organs called **ovaries** begin producing eggs. Unlike the male, most of the reproductive organs of the female are internal. The ovaries are located in the lower part of the body cavity. Each of the two ovaries is about the size and shape of an almond. About once a month an egg is released from an ovary. This process is called **ovulation** (ahv yuh LAY shun). The two ovaries take turns releasing the eggs. One month, the first ovary releases an egg; next month, the other ovary releases an egg and so on. When the egg is released, it enters the oviduct. If the egg is fertilized by a sperm, it will occur in an oviduct. Cilia help sweep the egg through the oviduct to the uterus. The **uterus** is a hollow, pear-shaped, muscular organ with thick walls in which a fertilized egg develops. The lower end of the uterus is connected to the outside of the body by a muscular tube called the **vagina.** The vagina is also called the birth canal because a baby passes through this passage-

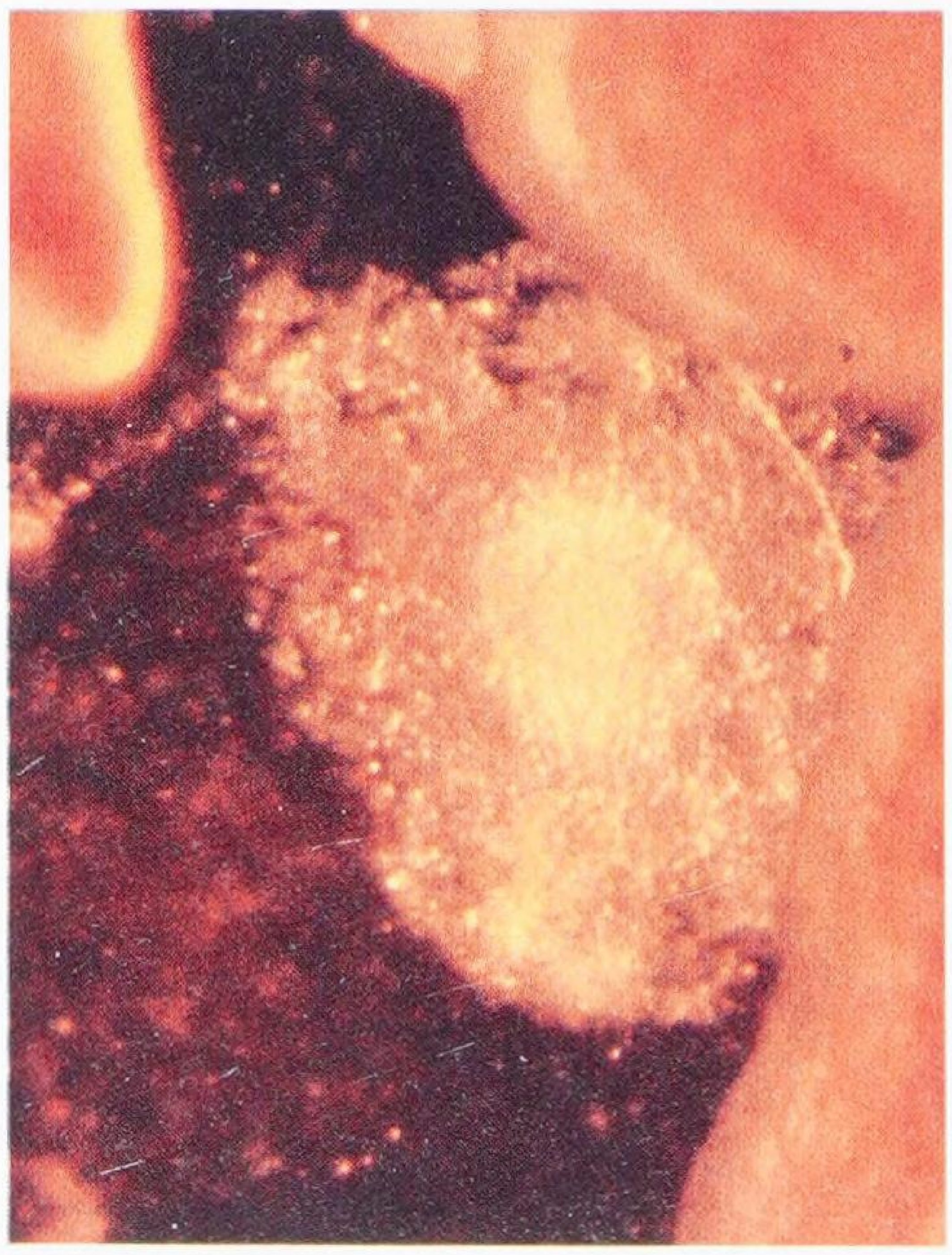
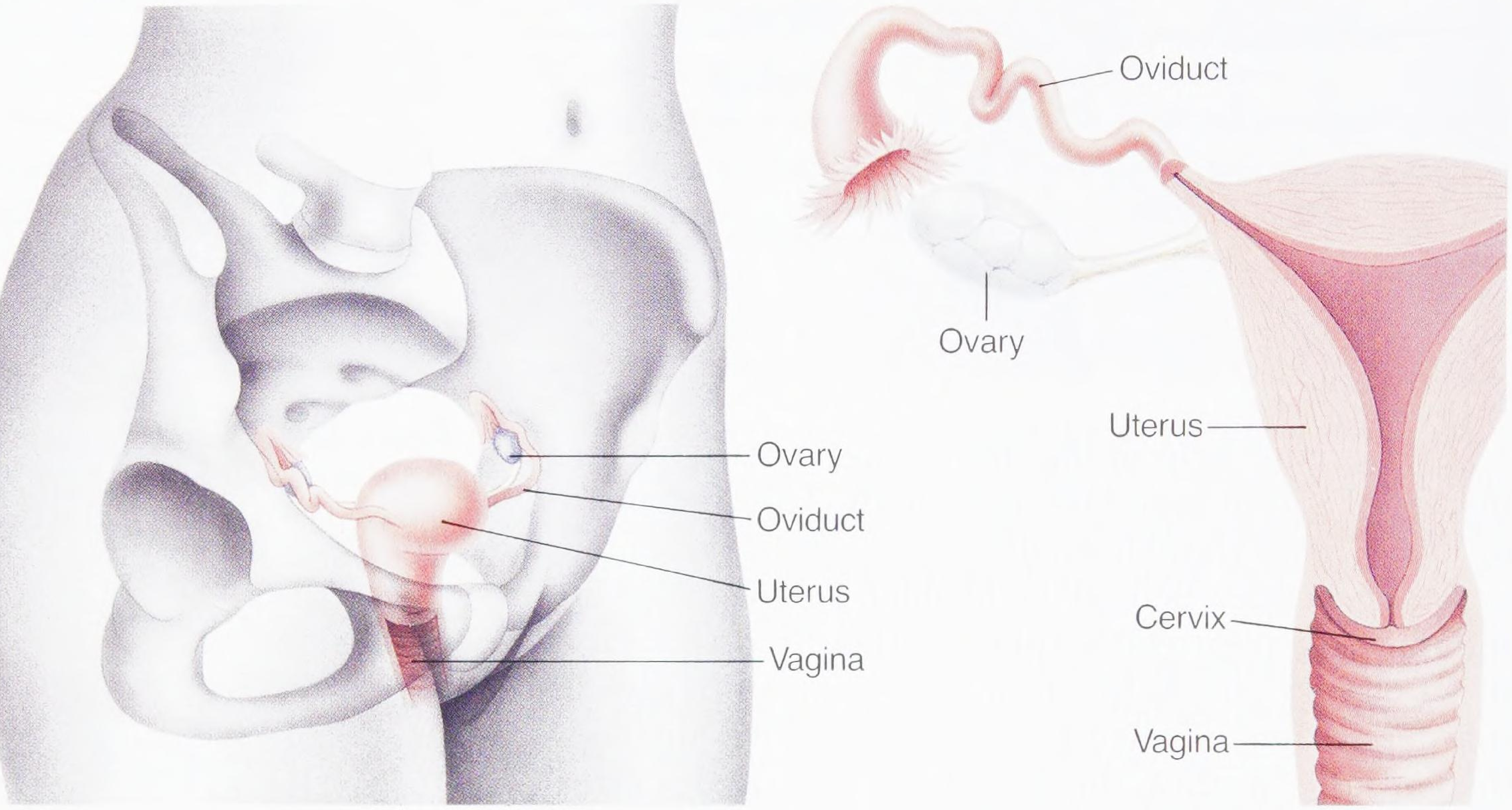


Figure 23-2. In the center of the photograph is an egg just released from an ovary. It will begin its journey down the oviduct.

way when being born. Figure 23-3 shows the structures of the female reproductive system.

Figure 23-3. The structures of the female reproductive system are shown from the front (right) and the side (left).



The Menstrual Cycle

Before and after an egg is released from an ovary, the uterus undergoes certain changes. The **menstrual cycle** is the monthly cycle of changes in the female reproductive system. This cycle of a human female averages 28 days. However, the cycle can vary in some individuals from 20 to 40 days. The changes include the maturing of an egg and the preparation of the uterus to receive a fertilized egg, as shown in Figure 23-4. When an egg inside an ovary matures, the lining of the uterus thickens as it prepares for a fertilized egg.

When does the menstrual cycle begin?

On approximately day 14 of a 28-day menstrual cycle, an egg is released from an ovary. It remains alive for about 24 to 48 hours. During this time, it travels along the oviduct. A female can become pregnant at this time in her menstrual cycle. The egg can be fertilized if live sperm are present in the oviduct 48 hours before or after ovulation. If an egg is not fertilized in the oviduct, it disintegrates. The thickened lining of the uterus is shed and bleeding occurs. This monthly discharge of the lining of the uterus and blood through the vagina is called

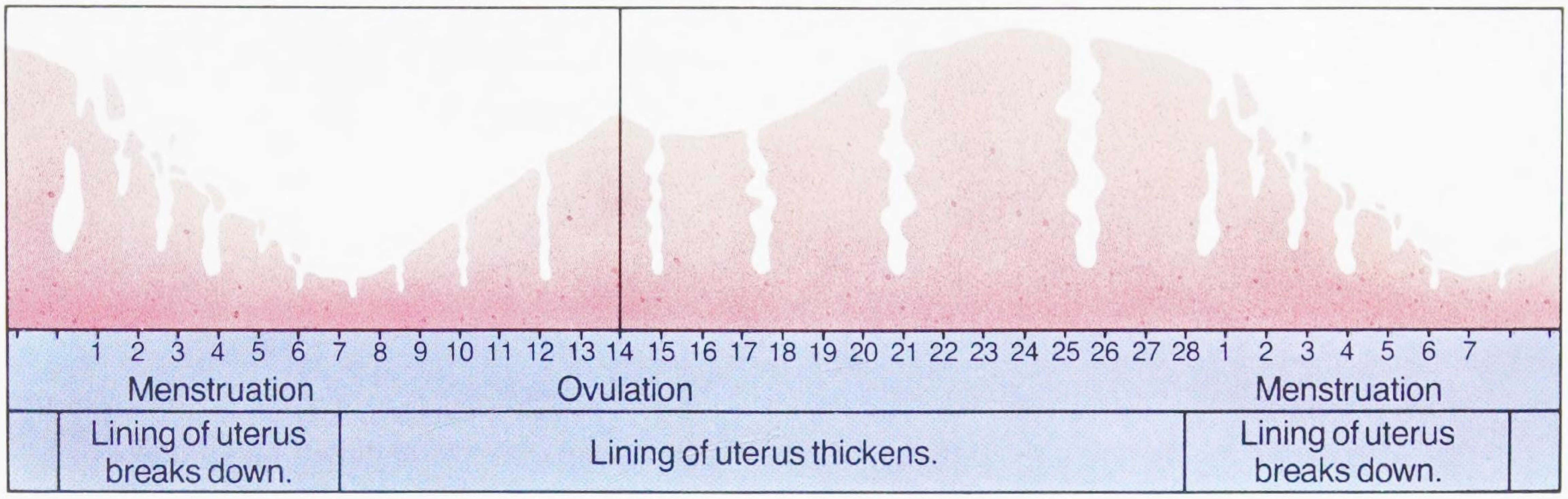

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 1 2 3 4 5 6 7
Menstruation
Ovulation
Menstruation
Lining of uterus breaks down.
Lining of uterus thickens.
Lining of uterus breaks down.

Figure 23-4. The menstrual cycle begins on day one of menstruation. Ovulation occurs near day 14 of a regular 28-day cycle.

menstruation (men STRAY shun). The menstrual period usually lasts from four to six days and is a normal function of the female reproductive system.

When menstruation begins, another egg begins maturing. The uterus again prepares for the egg. Hormones from the pituitary gland and the ovaries control the events of the menstrual cycle.

Menstruation begins when a girl's reproductive organs have matured. For most females, the first menstrual period happens between ages 8 and 13 and continues until age 45 to 55. Then, there is a gradual reduction of ovulation and menstruation. **Menopause** occurs when the menstrual cycle becomes irregular and eventually stops.

When the reproductive systems of males and females become mature, sperm and eggs are produced. The reproductive process allows for the species to continue.

SECTION REVIEW

1. What is the major function of a reproductive system?
2. Trace and label the route of sperm movement through the male reproductive system.
3. List the organs of the female reproductive system and describe their functions.
4. Explain the cause of menstrual flow.
5. **Apply:** What happens to the lining of the uterus after a women goes through menopause?
6. **Connect to Chemistry:** Find out why adolescent females often require additional amounts of iron in their diet.

Sequencing

Skill Builder

Sequence the movement of an egg through the female reproductive system. If you need help, refer to Sequencing in the **Skill Handbook** on page 680.

ACTIVITY 23-1

Interpreting Diagrams

Problem: *What happens to the uterus during a female's monthly cycle?*

Materials

- paper and pencil

Procedure

1. The diagrams below show what is explained in the previous section on the menstrual cycle.
2. Study the diagrams and their labels.
3. Use the information in Section 23-1 and the diagrams to complete a table like the one shown.

Data and Observations

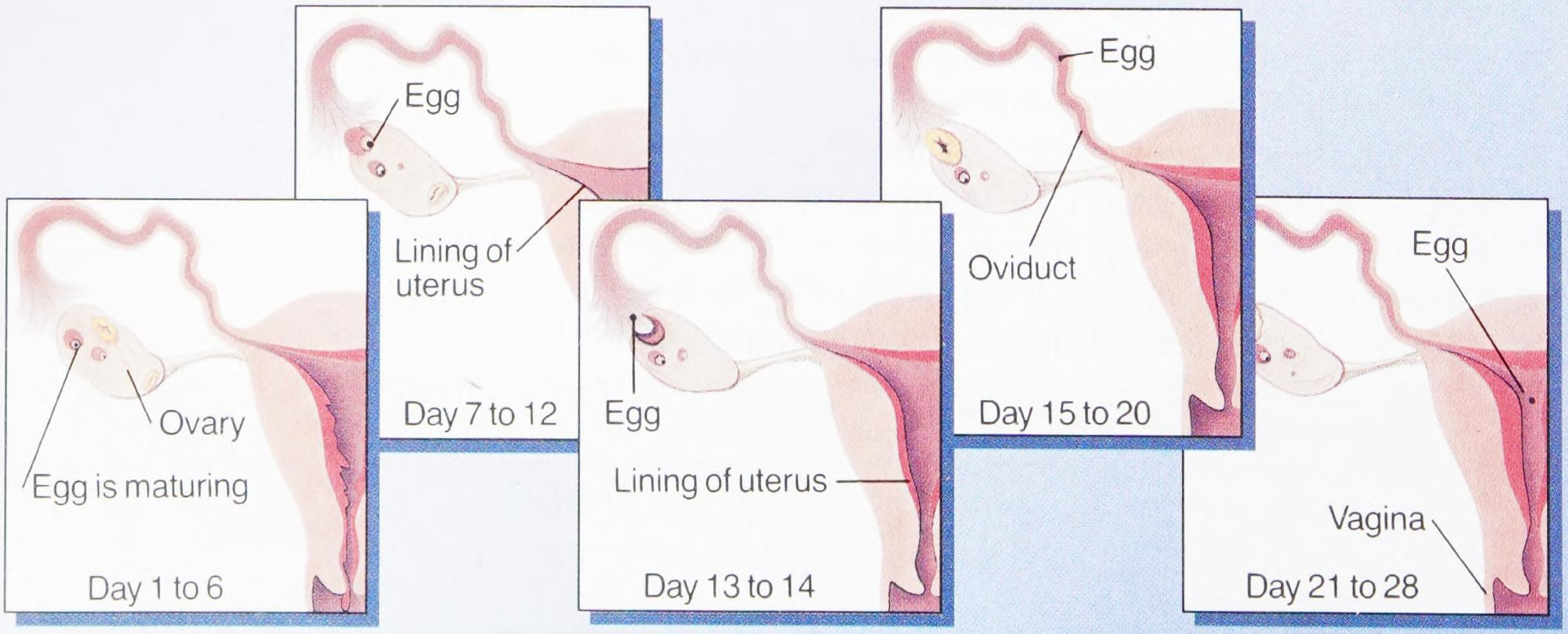
Days	Condition of uterus	What happens
1 – 6		
7 – 12		
13 – 14		
15 – 28		

Analyze

1. What do the diagrams represent?
2. What do the pink- or red-colored parts of the diagrams represent?
3. How does the figure caption relate to the diagram in Figure 23-4?
4. At what stage in the menstrual cycle is the uterine lining the most thickened?

Conclude and Apply

5. How long is the average menstrual cycle?
6. How many days does menstruation usually last?
7. How are the diagrams different?
8. On approximately what day in a 28-day cycle is the egg released from the ovary?
9. On what days does the lining of the uterus build up?
10. Why is this process called a cycle?
11. How many days before menstruation does ovulation usually occur?
12. *Interpret* the diagram to explain the menstrual cycle.


Egg is maturing
Ovary
Day 1 to 6
Egg
Lining of uterus
Day 7 to 12
Egg
Lining of uterus
Day 13 to 14
Egg
Oviduct
Day 15 to 20
Egg
Vagina
Day 21 to 28

Fertilization to Birth

23-2

Objectives

- Describe how an egg becomes fertilized.
- Identify the major events in the stages of development of an embryo and fetus.
- Differentiate between fraternal and identical twins.

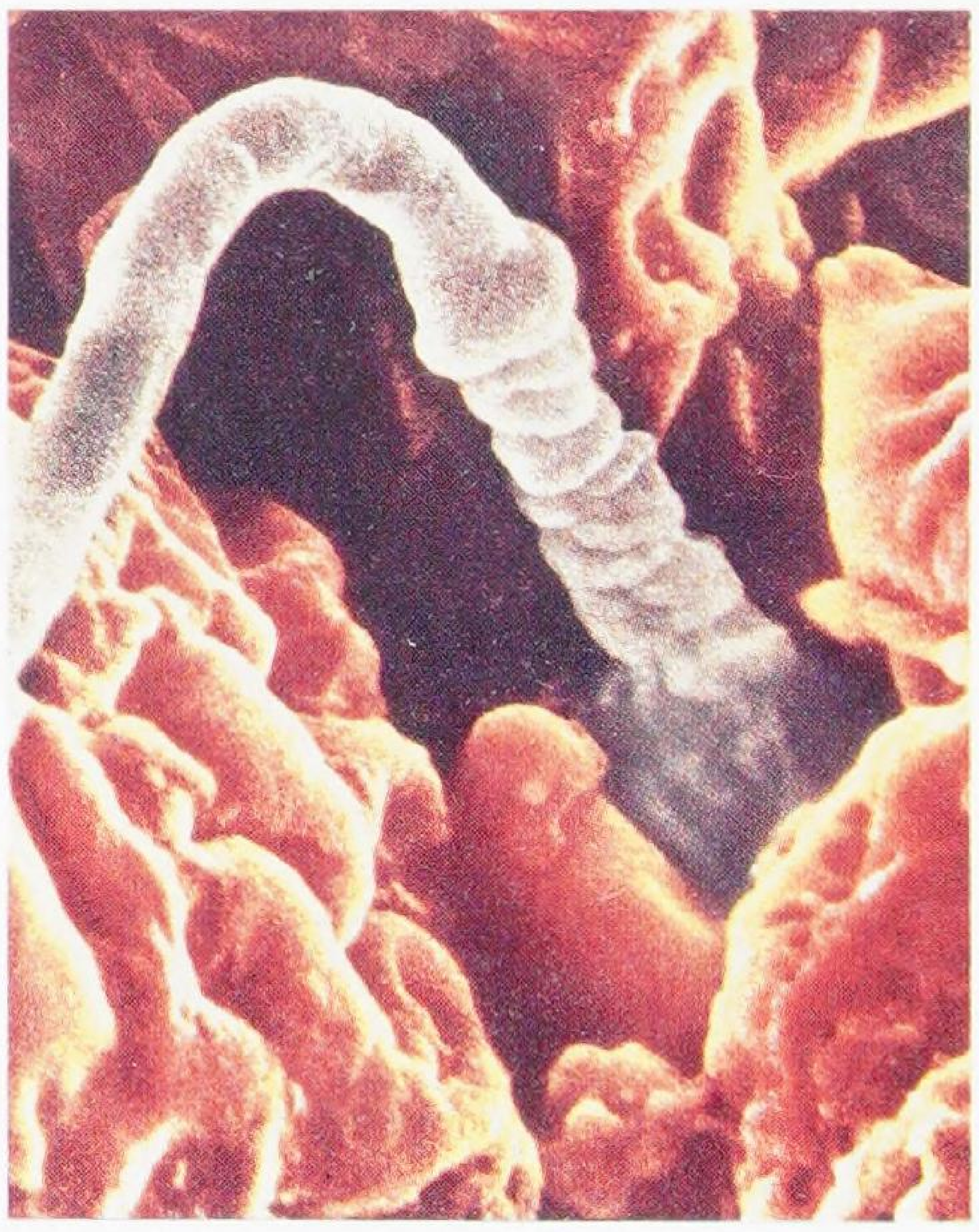
New Science Words

pregnancy
embryo
amniotic sac
fetus

Fertilization

Before the invention of powerful microscopes, some people imagined a sperm to be a miniature person that grew in the uterus of a female. Others thought the egg contained a miniature individual that started to grow when stimulated by semen. In the latter part of the 1700s an Italian naturalist, Lazzaro Spallanzani, showed with experiments using amphibians that contact between an egg and sperm is necessary for life to begin development. With the formulation of the cell theory in 1839, scientists recognized that a human develops from a single egg that has been fertilized by a sperm. The uniting of a sperm with an egg is known as fertilization.

Figure 23-5. Only one sperm will fertilize an egg.



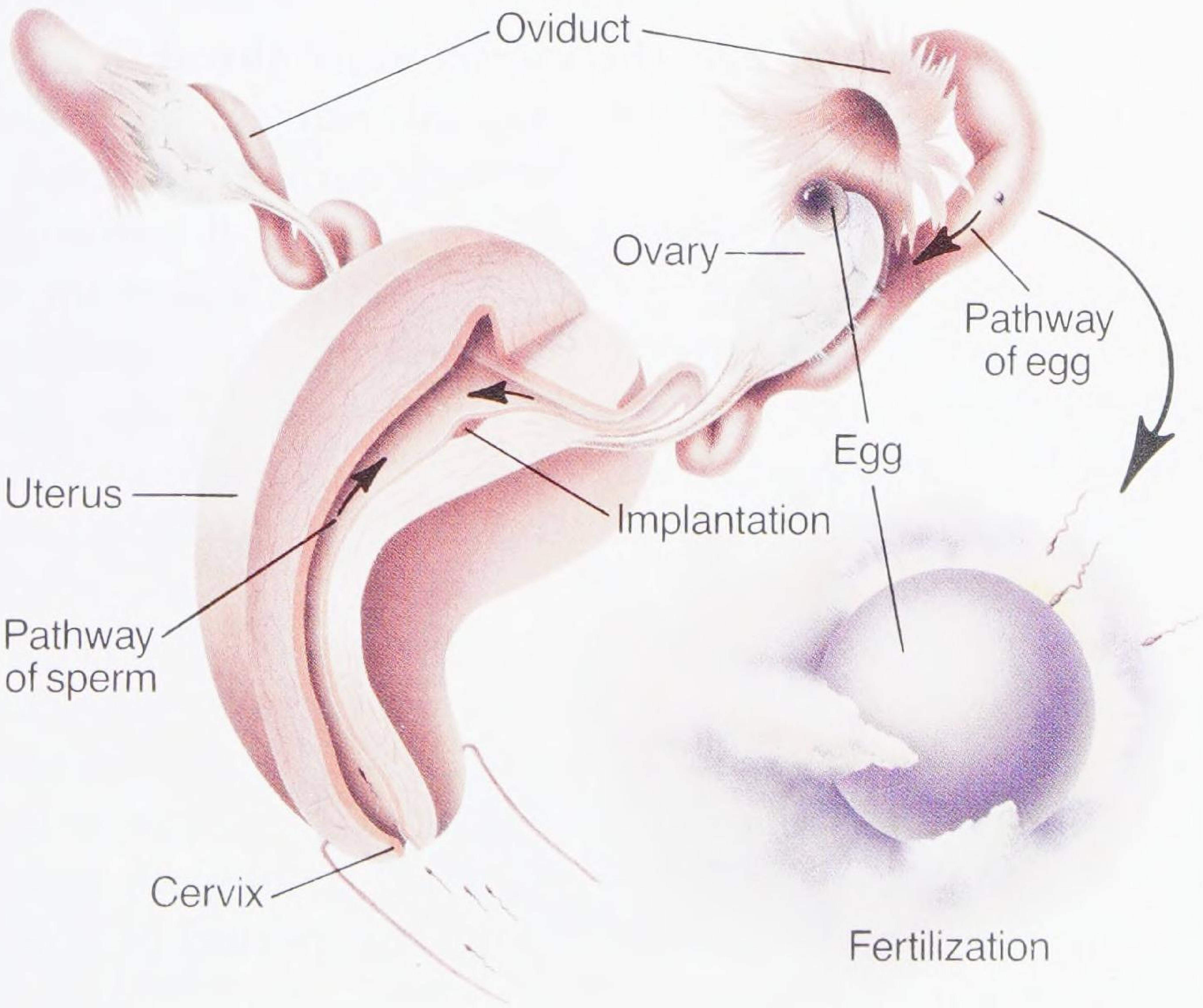


Figure 23-6. An egg is usually fertilized in an oviduct and is implanted in the uterus.

PROBLEM SOLVING

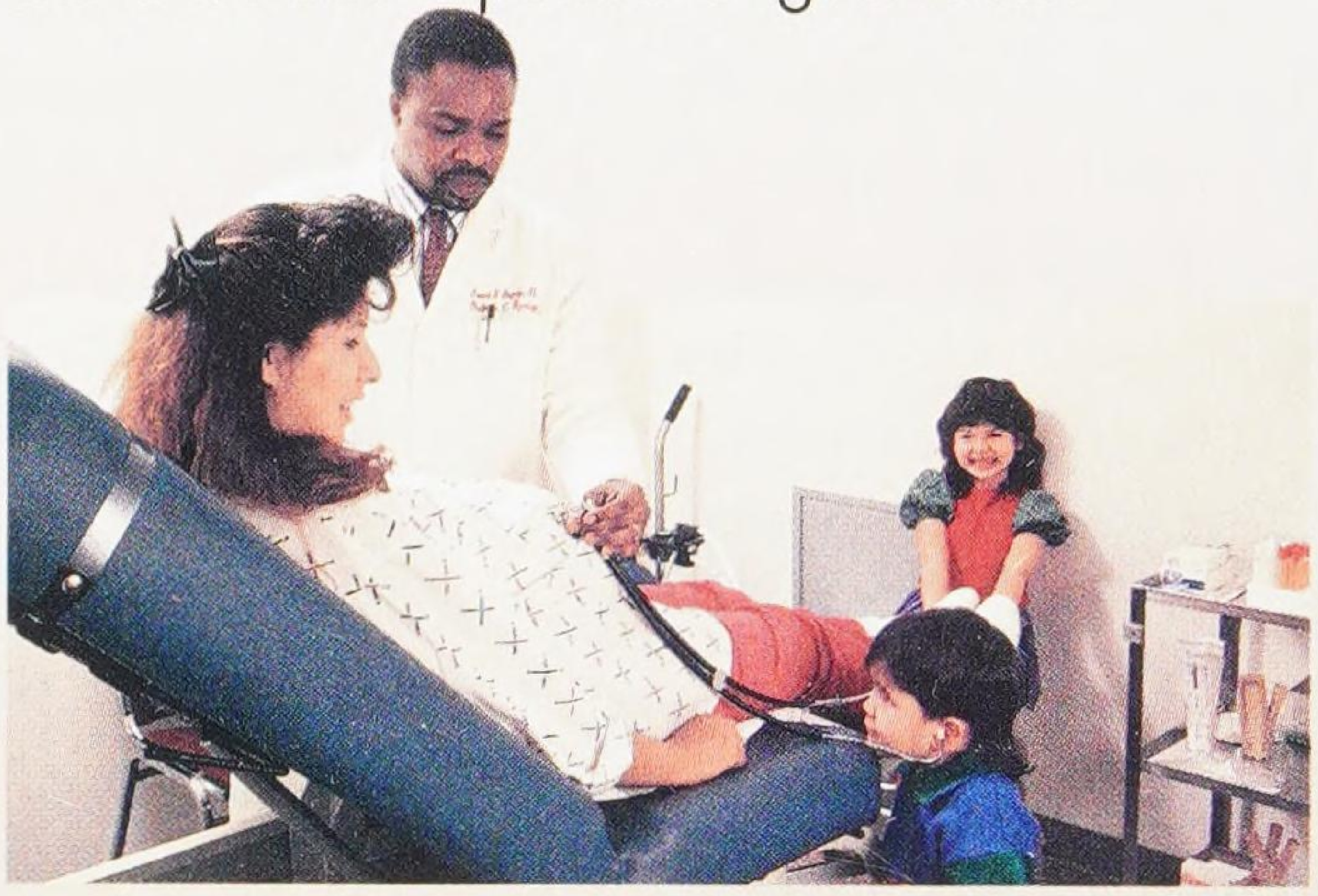
When Is the Baby Due?

One of the first questions expectant mothers ask is "When is the baby due?" The due date is important to the family of the baby. What does a family do to prepare for a baby? The date also is important for the obstetrician, a doctor who specializes in childbirth. This doctor keeps track of the growth of the fetus. The obstetrician is concerned about the health of the baby and the mother.

Doctors generally estimate the period of human gestation at nine and one-half menstrual cycles, or about 266 days from conception. This date is estimated from the beginning of the mother's last menstrual period. Conception is thought to have occurred two weeks later.

Researchers have recently measured the periods of gestation among a small group of women with normal pregnancies. They found that the median gestation period was longer than 266 days and think that the normal period of gestation might be longer. Why are doctors interested in the duration of gestation?

Think Critically: Identify the part of scientific investigation researchers need to do to determine a normal period of gestation?



Connect to...
Chemistry

Enzymes released from the head of a sperm break down the cell membrane of the egg and allow the sperm to enter the egg. *Relate* this to chromosomes and mitosis in the fertilized egg. *Infer* why no more than one sperm fertilizes an egg.

Sperm deposited into the vagina move through the uterus into the oviducts. Whereas only one egg is usually present, nearly 200 to 300 million sperm are deposited. Only one sperm will fertilize the egg. Once the sperm penetrates the outer surface of the egg, the egg sets up a chemical barrier to keep out the other millions of sperm. The nucleus of the sperm and the nucleus of the egg have 23 chromosomes each. When the egg and sperm unite, a zygote with 46 chromosomes is formed. Most fertilization occurs in an oviduct.

The zygote moves along the oviduct to the uterus. During this time, the zygote is dividing. After about seven days, the ball of cells is implanted in the wall of the uterus. The uterine wall has been thickening in preparation to receive a fertilized egg. Here the egg will develop for nine months until the birth of the baby. This period of time is known as **pregnancy.**

The Stages of the Embryo and Fetus

The outer cells of a fertilized egg attach to the wall of the uterus. During the first two months of pregnancy, the unborn child is known as an **embryo.** Nutrients from the wall of the uterus are received by the embryo through villi. Blood vessels develop from the villi and form the placenta (pluh SENT uh). The umbilical (um BIHL ih kul) cord attaches at the embryo's navel with the placenta. The umbilical cord transports nutrients and oxygen from the mother to the baby through arteries. Carbon dioxide and other wastes are carried through veins in the umbilical cord back to the mother's blood. Other substances in the mother's blood can pass to the embryo. These include drugs, toxins, and disease organisms. These substances can cause great harm to the embryo. For this reason, a mother should avoid harmful drugs, alcohol, and tobacco during pregnancy.

MINI-Lab

How long is an embryo?

Use the data from More Skill Builders, number 4, on page 549 and the data below. On a piece of paper, draw the size of the embryo at each date using a ruler. Using references, *describe* the event or structure taking place at that time of development.

End of month	Length
3	7.5 cm
4	15 cm
5	25 cm
6	30 cm
7	35 cm
8	40 cm
9	51 cm

During the third week of pregnancy, a thin membrane begins to form around the embryo. This is called the amnion or the amniotic sac and is filled with a clear liquid called amniotic fluid. The amniotic fluid in the **amniotic sac** helps cushion the embryo against blows and can store nutrients and wastes. This sac attaches to the placenta.

How is the embryo cushioned against blows?

During the first three months of development, all of an embryo's major organs form. A heart structure begins to beat and move blood through the embryo's blood ves-

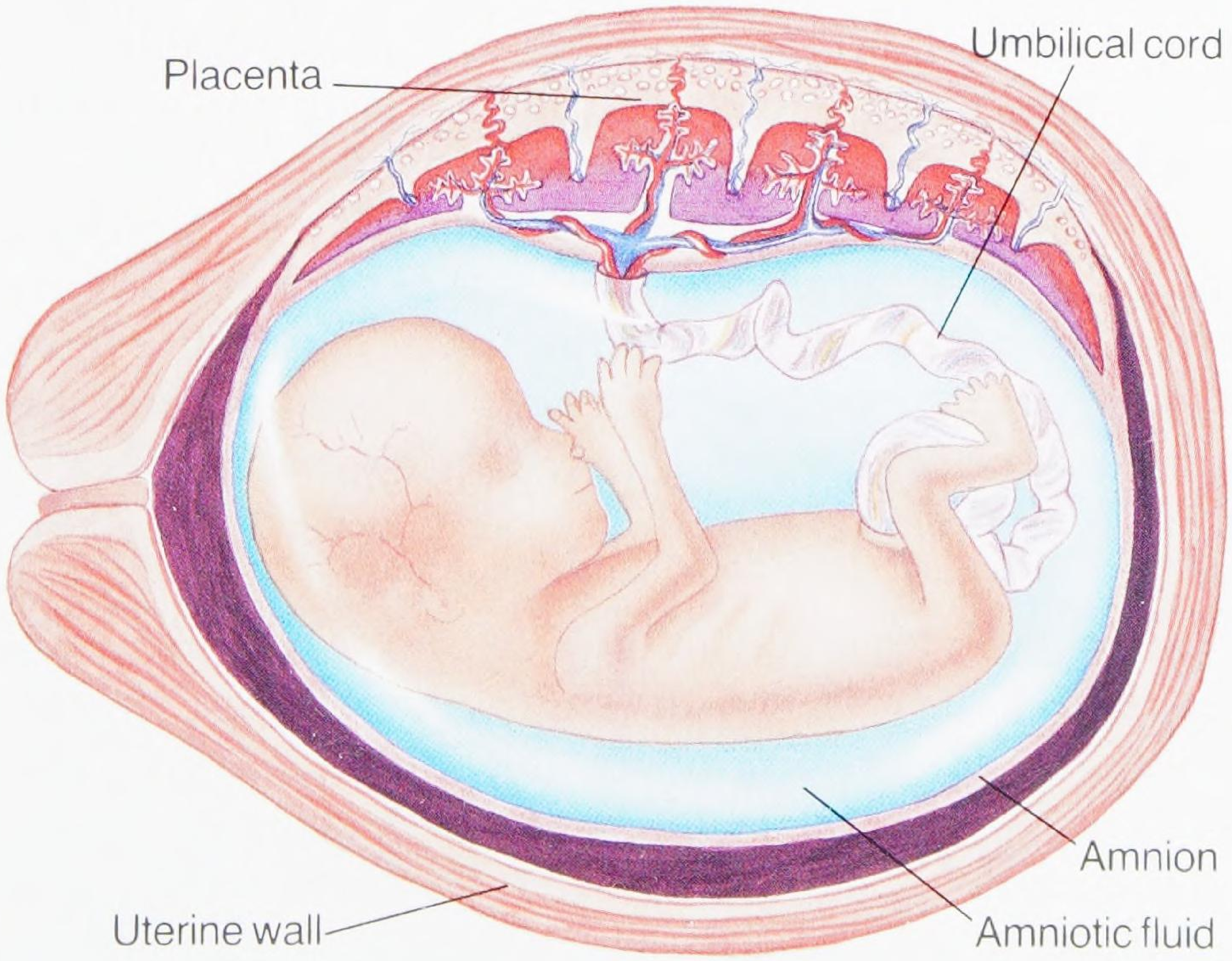


Figure 23-7. The developing embryo is surrounded by protective membranes.

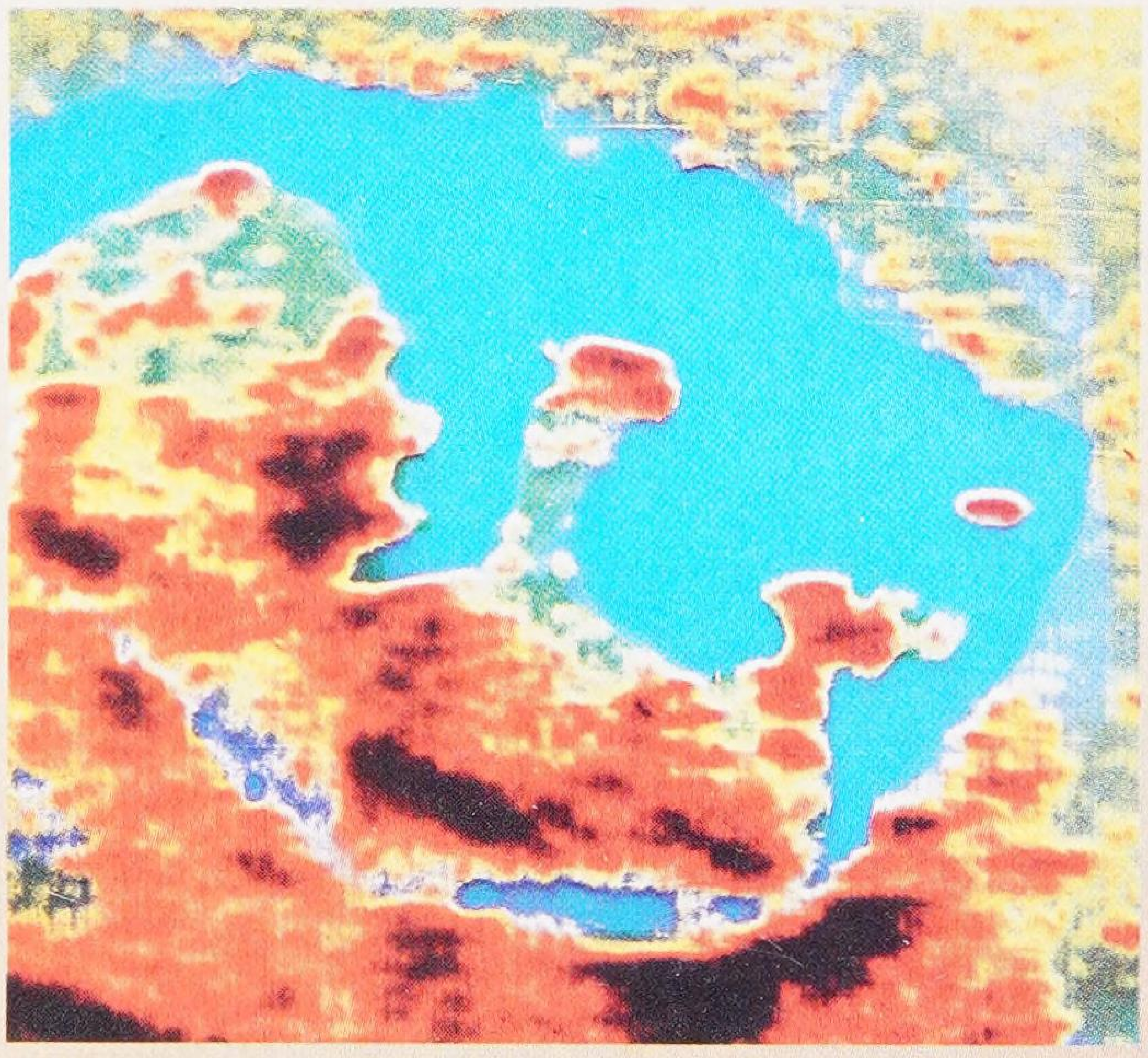
TECHNOLOGY

Operating in the Womb

Doctors performing fetal surgery may have patients that are only 24 weeks beyond conception and only inches in size.

Using ultrasound, doctors can see an image of the developing fetus in the womb and can detect fetal defects that frequently mean death soon after birth. One of these involves a hole in the diaphragm that allows the intestines, stomach, spleen, and liver to move into the chest cavity. When this happens, the growth of the fetus' lungs is stunted, and the baby is unable to breathe when born. The only hope has been to operate on the baby immediately following birth, but this is successful only 20 percent of the time. Now, doctors are able to operate on such a fetus while it is still in the uterus. To do this, a small incision is made in the mother's uterus. The fetus's chest is opened and abdominal organs are returned to their proper place. Finally, a patch is placed over the hole in the diaphragm. The baby now has a good chance to survive after birth.

Think Critically: What other prenatal conditions might be corrected using this method?



sels. At five weeks, the embryo is only as large as a single grain of rice, but there is a head with recognizable eye, nose, and mouth features. During the sixth and seventh weeks, tiny arms and legs develop fingers and toes.

After the first two months of pregnancy, the developing baby is called a **fetus** (FEE tus). At this time, body organs are present. Around the third month, the fetus is 8-10 cm long, the heart can be heard beating, and the mother may feel the baby's movements within her uterus. The fetus sucks its thumb. By the end of the seventh month of pregnancy, the fetus is 30 to 38 cm in length. Fatty tissue builds up under the skin, and the fetus appears less wrinkled. By the ninth month, the fetus usually has shifted to a head-down position within the uterus. The head usually is in contact with the opening of the uterus to the vagina. The fetus is about 50 cm in length and weighs from 2.5 to 3.5 kg. The baby is ready for birth.

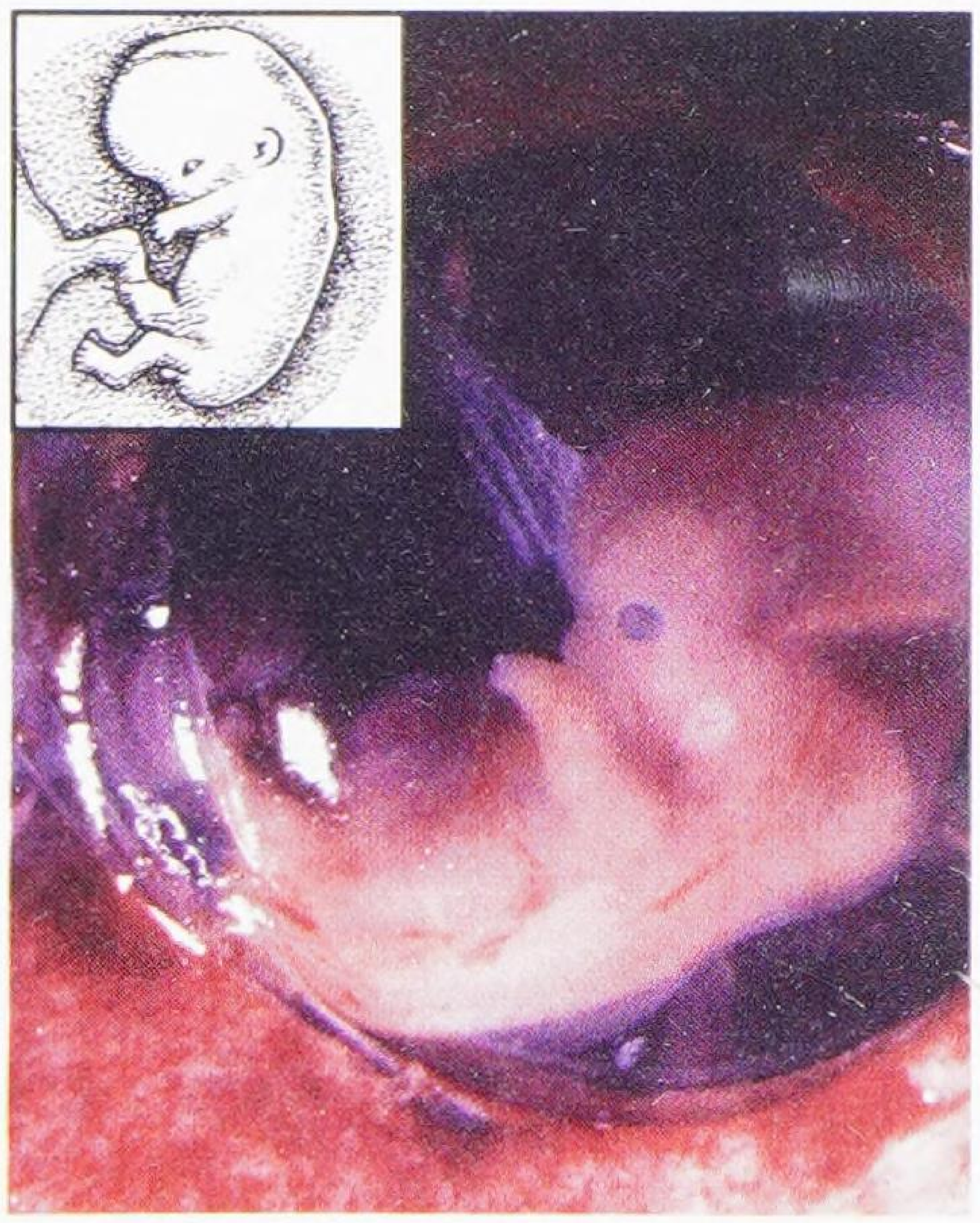


Figure 23-8. A two-month embryo shown enlarged in the photo and actual size in the drawing.

Multiple Births

In some cases, two eggs leave the ovary at the same time. If both eggs are fertilized and both develop, twins are born. When two different eggs were fertilized by two different sperm, the two babies are called fraternal twins. Fraternal twins may be two girls, two boys, or a boy and a girl. Fraternal twins do not always look alike. In other cases of twins, a single egg may split apart shortly after it is fertilized. Each part of the egg then develops and forms an embryo. Because both children developed from the same egg and sperm, they are identical twins. Each has the same set of genes. Identical twins must be either two girls or two boys. These twins look exactly alike.

You may know some twins. In what ways are they alike or different? Are they fraternal or identical twins? Triplets and other multiple births may occur when either three or more eggs are produced at one time or an egg splits into three or more parts.

A remarkable series of events changes a single fertilized egg into a baby with billions of cells. The mother's body prepares for the baby. Special tissues nourish and protect the developing embryo and fetus. After a nine-month period, the fetus is ready to live outside the mother's body.

Figure 23-9. Pick out the fraternal and identical twins.

SECTION REVIEW

1. What happens when an egg is fertilized?
2. What is one major event that occurs during the embryo and fetal stages?
3. Explain how twins are fraternal or identical.
4. **Apply:** Why can't identical twins be a girl and boy?
5. **Connect to Chemistry:** How are nutrients, oxygen, and wastes exchanged between the fetus and the mother?

Making and Using Graphs

Skill Builder

Make a graph of the embryo and fetus sizes and the months of development using this data: 1 month = 0.5 cm, 2 months = 3 cm, 3 months = 7.5 cm, 4 months = 15 cm, 5 months = 25 cm, 6 months = 30 cm, 7 months = 35 cm, 8 months = 40 cm, 9 months = 50 cm. If you need help, refer to Making and Using Graphs in the **Skill Handbook** on page 691.

23-3 Development after Birth

New Science Words

infancy
childhood
adolescence
adulthood

Objectives

- State the sequence of events of childbirth.
- Compare the stages of infancy and childhood.
- Relate adolescence to preparation for adulthood.

In Your JOURNAL

The Lamaze method of childbirth has become a popular technique. **In your Journal,** define what is it and tell why is it so popular?

Childbirth

After nine months of developing within the mother, the baby is ready to be born. Like all newborn living things, the baby will find itself suddenly pushed out into the world. Within the uterus and amniotic sac the baby was in a warm, watery, dark, and protected environment. In contrast, the new environment is cooler, drier, brighter, and not as well protected.

The process of childbirth begins with labor, the muscular contractions of the uterus. As the contractions increase in strength and frequency, the amniotic sac usually breaks and releases its fluid. This is known as "breaking water." Usually, over a period of hours, the contractions cause the opening of the uterus to widen to allow the baby to pass through. More powerful and frequent contractions push the baby out through the vagina into its new environment. Sometimes, the mother's pelvis is too small for the baby to fit through or the baby is in the wrong position for birth. In cases like this, the baby is delivered through an incision in the mother's uterus and abdomen. This surgery is called cesarean section.

What is cesarean section?

At birth, the baby is still attached to the umbilical cord and placenta. The person assisting with the birth of the baby ties the cord and then cuts it. The scar that later forms where the cord was attached is the navel. Soon after the baby's delivery, contractions expel the placenta from the mother's body. The baby takes its first breath of oxygen without the umbilical cord. The baby may cry. Crying forces air into its lungs.

Infancy and Childhood

The first four weeks after birth are known as the neonatal (ne o NA tal) period. *Neonatal* means "new born." During this time, the baby adjusts to life outside of the uterus. Body functions such as respiration, digestion, and excretion are now performed by the baby rather than through the placenta. Unlike some other living things, the human baby must depend on others to survive. A newborn colt begins walking a few hours after its birth. The human baby is fed and has its diaper changed. It is not able to take care of itself.

The next stage of development is **infancy,** the period from neonatal to one year. It is a period of rapid growth and development for both mental and physical skills. An early skill is the ability to smile that usually begins around six weeks of age. At four months, most babies can laugh, sit up when propped, and recognize their mothers' faces. At eight months, the infant is usually able to say a few simple words, such as "mama" and "kitty." One of the major events within the first year is the ability to stand unsupported for a few seconds.

After infancy is the **childhood** stage, which lasts until age 12. The physical growth rate for height and weight is not as rapid as in infancy. However, there is development of muscular coordination and mental abilities. By 18 months, the child is able to walk without help. Between two and three years, the child controls his or her bladder and bowel. At age three, the child can speak in simple sentences. By age five, many children can read a limited number of words. Throughout this stage, children develop their ability to speak, read, write, and reason. At the same time, children also mature emotionally and learn how to get along with other people. Find out how old you were when you began to talk. What were your first words?

Science and MATH

Cotton diapers can be reused up to 100 times and decompose in one to six months! Disposable diapers take up to 500 years to decompose. **In your Journal,** *calculate* the cost of disposable diapers for a year if an average of eight are used per day.

MINI-Lab

What is the immunization schedule for babies and young children?

Find out when and what vaccines are given to protect babies and young children. *Compare* your own immunization record. Record your own record **in your Journal.** What boosters were you given? What immunizations does your school require?

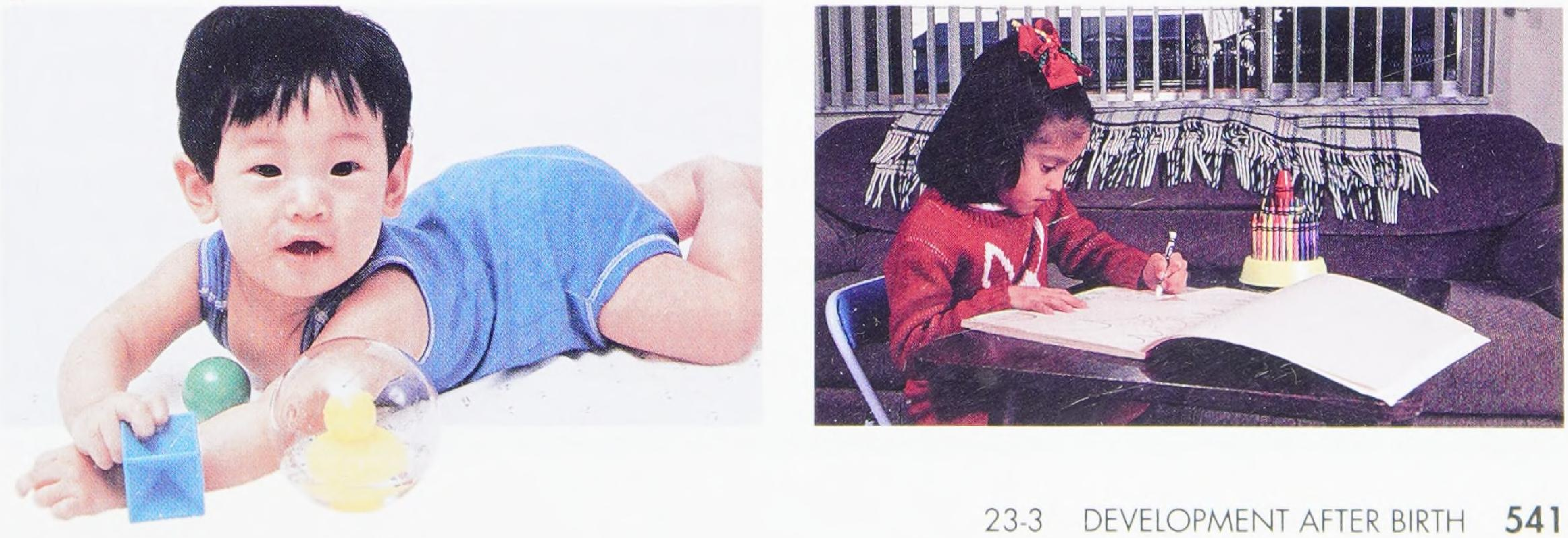


Figure 23-10. Compare the different abilities of an infant (a) and a six-year old (b).

Adolescence

The next stage of development is adolescence; you are in this stage. **Adolescence** begins from ages 12 to 14. A part of adolescence is puberty. As you read earlier, puberty is the time of development when a person becomes physically able to reproduce. For girls, puberty occurs between ages 8 and 13. For boys, puberty occurs between ages 13 and 15.

During puberty, hormones are produced by the pituitary gland that cause changes in the body. The hormone FSH helps produce reproductive cells. LH helps with the production of other hormones. As a result, secondary sex characteristics result. In females, the breasts develop, pubic and underarm hair appears, and fatty tissue is added to the buttocks and thighs. In males, the hormones cause the growth of facial, pubic, and underarm hair; a deepened voice; and an increase in muscle size. Many begin to experience feelings of sexual attraction.

Adolescence also is a time of a growth spurt. Are you shorter or taller than your classmates? Because of differences in the time hormones begin functioning among individuals and between males and females, there are differences in boys' and girls' growth rates. Girls often begin their increase in growth between the ages of 11 and 13 and end at ages 15 to 16. Boys usually start their growth spurt at ages 13 to 15 and end at 17 to 18 years of age. Hormonal changes also cause underarm sweating and acne, requiring extra cleanliness and care. All of these physical changes can cause you to feel different or uncomfortable. This is normal. As you move through the period of adolescence, you will find that you will become more coordinated, be better able to handle problems, and gain improved reasoning abilities. You'll find that you enjoy spending more time with your friends.

Figure 23-11. Adolescence is a time for many changes.

Connect to...

Physics

At birth, the head of the newborn is about one-quarter of the body length. *Measure* classmates and **in your Journal,** *calculate* the proportion of the head length to body length for adolescents.

Adulthood

The final stage of development is that of **adulthood.** It begins with the end of adolescence and extends to old age. There are several stages of adulthood. The early years of adulthood occur when people are in their 20s. Many of these adults are completing an education, finding employment, and possibly marrying and beginning a family. The growth of the muscular and skeletal system stops.

People in their 30s to 50s make up the stage of middle adulthood. During these years, physical strength begins to decline. As a person ages, blood circulation and respiration are less efficient. Bones become more brittle, and the skin's elastic tissues are lost, causing the skin to become wrinkled. This group is busy with family and work commitments. People in this group often care for aging parents as well as children.

Think about someone you know over age 65. How is that person alike or different from you? The young-old age group includes people from 65 to 74 years old. Around this age, many people retire. To fill their time, they may take up hobbies, travel, or volunteer at hospitals, schools, and community organizations. Many older people are an active part of society. The old-old age group is made up of people 75 years and older. Many people in this group are frail and need assistance in meeting their needs.

After birth, the stages of development of the human body begin with a baby making adjustments to a new environment. From infancy to adolescence, the body's systems mature, enabling the person to be physically and mentally ready for adulthood. During the next 50 years or longer, people live their lives making contributions to family, community, and society. Throughout the life cycle, people who care for their health enjoy a higher quality of life.

Figure 23-12. Many people in the 65 to 74 year age group continue to work.

In Your JOURNAL

Interview someone who's over 60 years of age. Find out what his or her life was like when he or she was your age. What does the person like to do now? Write a report **in your Journal** to share with the class.

SECTION REVIEW

1. What are major events during childbirth?
2. Compare infancy with childhood.
3. How does the period of adolescence prepare you for the stage of adulthood?
4. Define the stages of adulthood.
5. **Apply:** Why is it hard to compare the growth and development of different teenagers?
6. **Connect to Physics:** Compare the growth of boys and girls during childhood, ages 18 months through 13 years.

Skill Builder

Outlining

Prepare an outline of the various life stages of human development from neonatal to adulthood. If you need help, refer to Outlining in the **Skill Handbook** on page 681.

SCIENCE & SOCIETY

23-4 Aging

New Science Words

catalase

Objectives

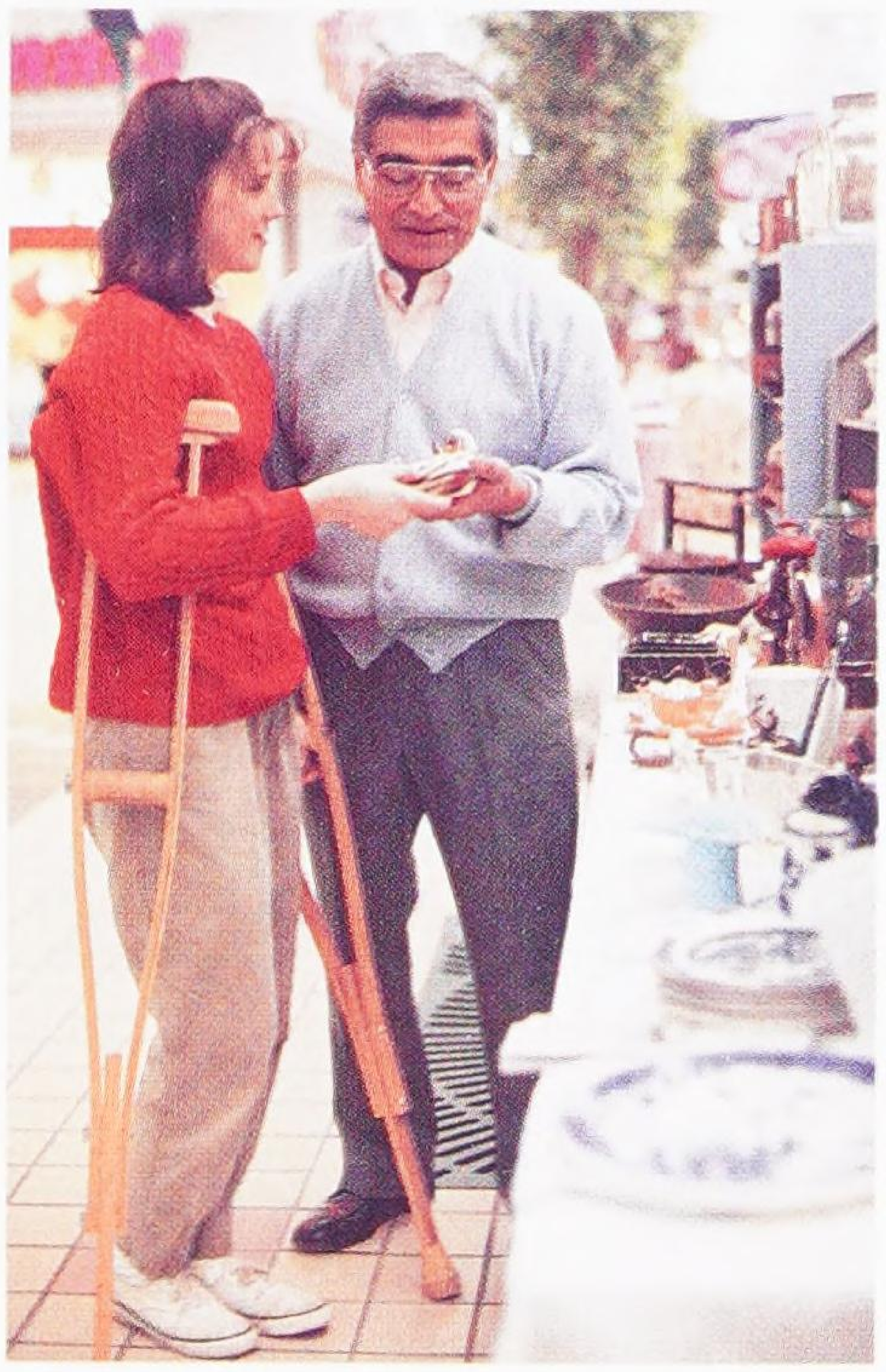
- Discuss concerns in society for the elderly.
- Explain the chemical process of aging.

Prolonging Life

Take a look in a mirror and try to picture yourself at 65 years of age. Most junior high school students probably don't give too much thought to aging. In fact, you are probably eager to be older than you are. You may view people older than yourself as having freedom, money, and many privileges. However, if you think about some elderly persons that you know, you may be reminded of some disadvantages of growing older. There are many chronic diseases associated with people who are in their 60s, 70s, and 80s. Conditions associated with aging include Alzheimer's disease, arthritis, osteoporosis, diabetes, cancer, and heart disease. An older person also may have less energy than when he or she was younger and have memory loss. Hearing and sight may decline.

You might be aware of the rising costs of health care. This especially affects the elderly. Many older persons cannot afford adequate health care. This problem contributes to a general decline in health maintenance. It is estimated that within 60 years, almost a fourth of the population will be age 65 and older. With a growing older population, adequate health care for older persons is a real concern in our country.

Congress has set aside millions of dollars for research and programs on aging. Many persons are concerned that living longer does not mean living healthfully. No one wants to live 20 years longer if its means enduring a painful, chronic disease. However, the goal of many researchers is to increase years of health, not just lengthen life. In the past several years, researchers and medical professionals have found that a person can do much to promote his or her health. This includes eating right, exercising regularly, monitoring stress, and not smoking.



Connect to... Chemistry

Osteoporosis is a disease characterized by the deterioriation of bone. *Predict* why the diet of some people can result in this disease.

By choosing healthful habits, some people will have much healthier lives than others. However, everyone does age. The body breaks down as nerves degenerate, the immune system deteriorates, hormones change, and death approaches.

Researchers believe that certain genes are responsible for the aging process. It is believed that the chemical destruction of cells by hydrogen peroxide plays a large role in the aging process. Hydrogen peroxide is produced by many cellular reactions. Dr. Glenn Bewley at North Carolina State University found that he could isolate in fruit flies the gene that produces **catalase,** the enzyme that breaks down hydrogen peroxide. When he did this, less catalase was produced and the life span of the fruit flies was shortened. If the gene for catalase production can be overexpressed, meaning producing more catalase, a greater amount of hydrogen peroxide would be broken down. Fewer body cells would be damaged. If researchers developed a way to overexpress the gene for catalase, would it even be useful?

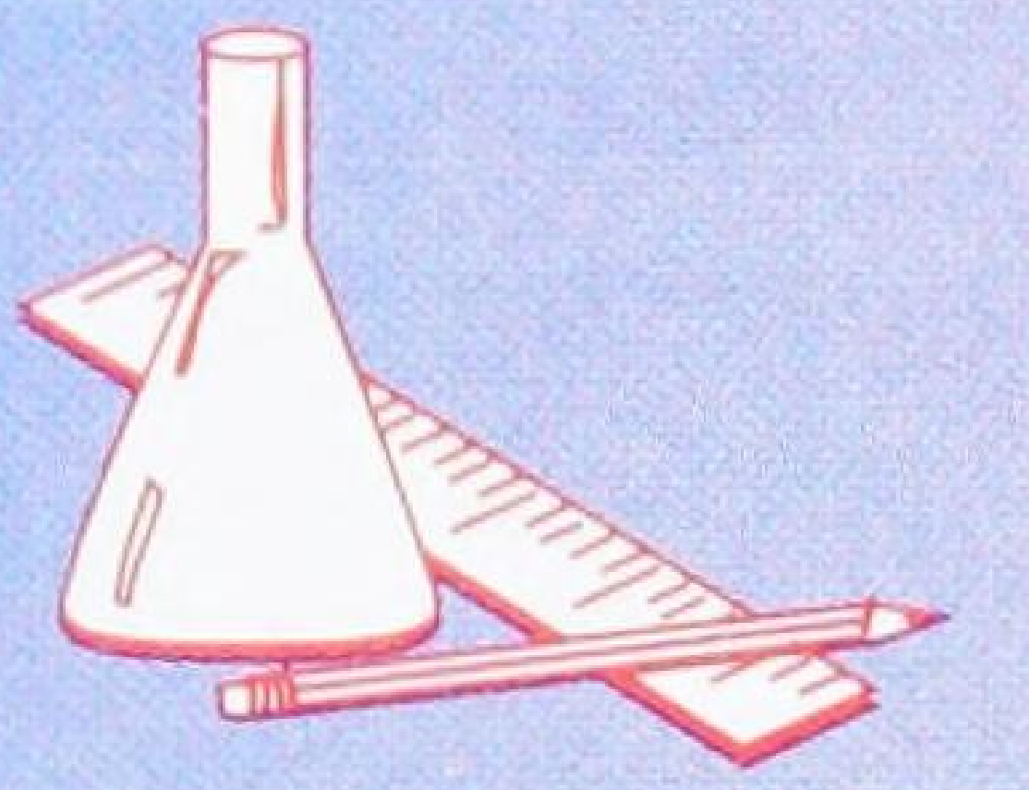
SECTION REVIEW

1. What can you do now to increase your years of health?
2. What role is catalase believed to play in the aging process?
3. **Connect to Chemistry:** Find out how wrinkles form in the skin of adults.

SCIENCE & SOCIETY

You Decide!

The life spans of many people are increasing due to the many new treatments for illness and disease doctors and scientists are discovering. In 1960, the average life expectancy for women was 73 years and 67 years for men. In 1988, it increased to 78 years for women and 72 years for men. Although people are living longer, many can't live on their own. They must depend on relatives and friends to help them with basic needs. Many also spend the rest of their lives dependent on medicine and medical technology. Do you think life should be extended when the person can no longer maintain the quality of life they once had?



ACTIVITY 23-2

Average Growth Rate in Humans

Problem: *Is average growth rate the same in males and females?*

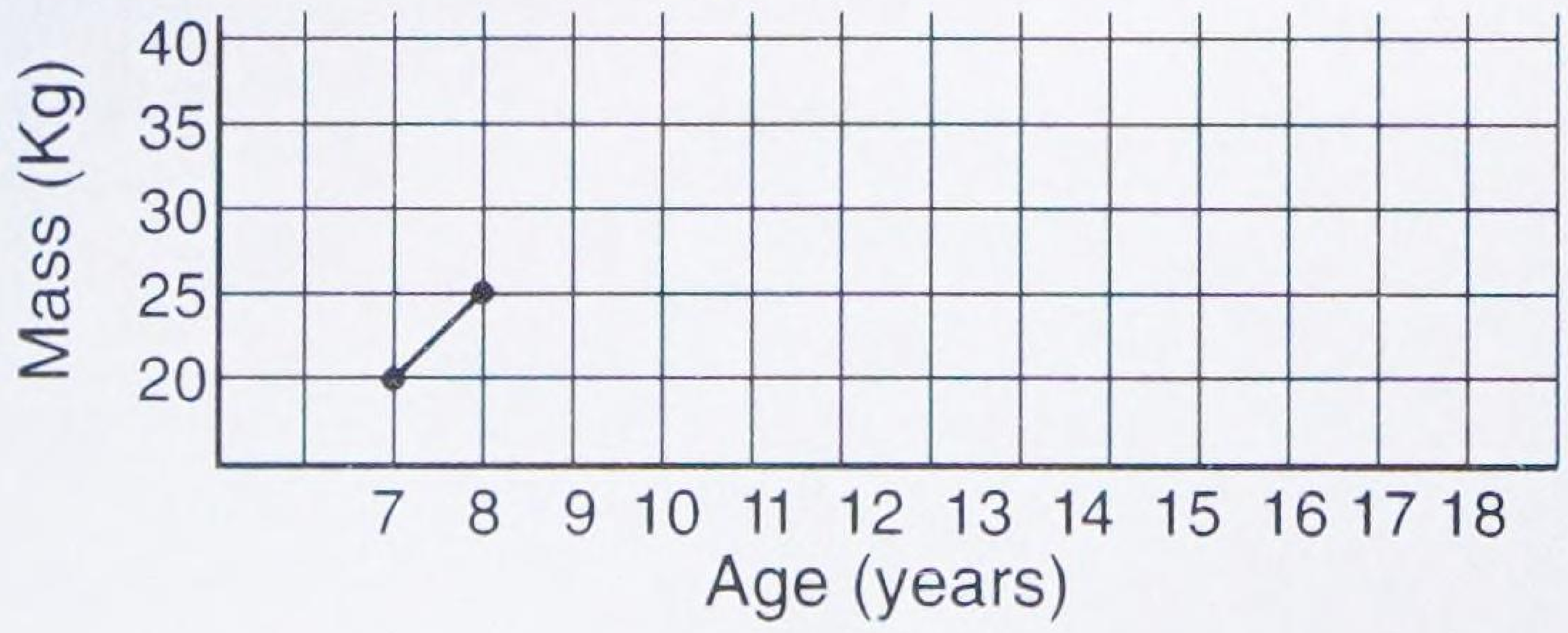
Materials

- graph paper
- red and blue pencils

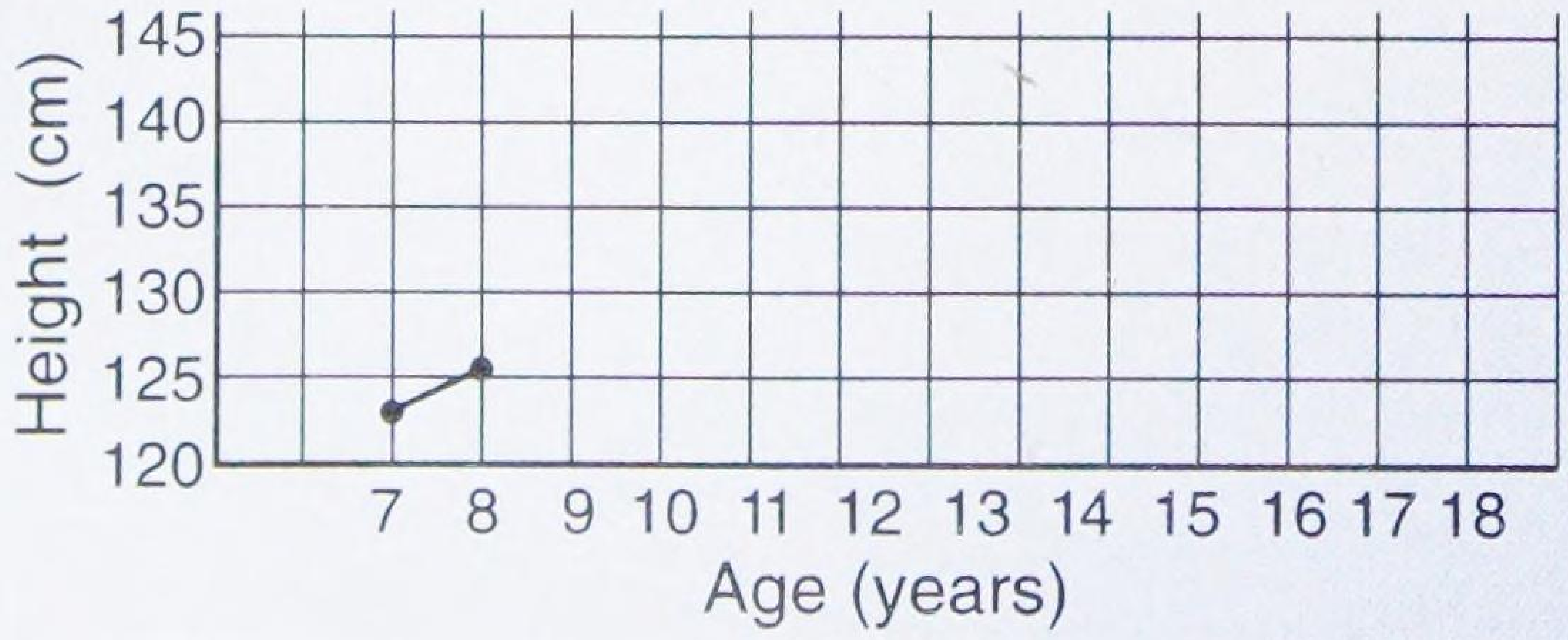
Procedure

1. Construct a graph similar to graph A below. Plot mass on the vertical axis and age on the horizontal axis.
2. Plot the data given under Data and Observations for the average female growth in mass from ages 8 to 18. Connect the points with a red line.
3. On the same graph, plot the data for the average male growth in mass from ages 8 to 18. Connect the points with a blue line.
4. Construct a separate graph similar to graph B below. Plot height on the vertical axis and age on the horizontal axis.
5. Plot the data for the average female growth in height from ages 8 to 18. Connect the points with a red line. Plot the data for the average male growth in height from ages 8 to 18. Connect the points with a blue line.

a Average growth in mass



b Average growth in height



Data and Observations

Averages for Growth in Humans

Age	Mass (kg)		Height (cm)	
	Female	Male	Female	Male
8	25	25	123	124
9	28	28	129	130
10	31	31	135	135
11	35	37	140	140
12	40	38	147	145
13	47	43	155	152
14	50	50	159	161
15	54	57	160	167
16	57	62	163	172
17	58	65	163	174
18	58	68	163	178

Analyze

1. Up to what age is average growth in mass similar in males and females?
2. Up to what age is average growth in height similar in males and females?

Conclude and Apply

3. Between what ages do females increase most in height?
4. During what ages do males increase most in height?
5. When does the mass of females change most?
6. How can you explain the differences in growth between males and females?
7. *Interpret* the data to find if the average growth rate is the same in males and females.

CHAPTER REVIEW

SUMMARY

23-1: Human Reproduction

1. The reproductive system allows new organisms to be formed.

2. The testes produce sperm that exit the male through the penis.

3. The female ovary produces an egg that can be fertilized to produce a zygote that develops within the uterus.

4. When an egg is not fertilized, it disintegrates; the lining of the uterus is shed.

23-2: Fertilization to Birth

1. After fertilization, the zygote undergoes developmental changes to become an embryo surrounded by amniotic fluid, then a fetus.

2. The uterine muscles contract to push the baby out of the mother's uterus and vagina.

3. Twins occur when two eggs are fertilized or when a single egg splits after fertilization.

23-3: Development after Birth

1. Birth begins with labor, muscular contractions of the uterus. The amniotic sac breaks, then usually after several hours, the contractions force the baby out of the body.

2. Infancy is the stage of development from neonatal to one year. It is a period of rapid growth of mental and physical skills. Childhood, which lasts to age 12 is marked by development of muscular coordination and mental abilities.

3. Adolescence is the stage of development when a person becomes physically able to reproduce. The final stage of development, adulthood, consists of many stages. All physical growth is complete.

23-4: Science and Society: Aging

1. Many conditions are associated with aging, including cancer, heart disease, and diabetes. Due to rising health care costs, many elderly are unable to get proper medical care.

2. Researchers believe the chemical hydrogen peroxide produced in cells plays a large role in the aging process.

KEY SCIENCE WORDS

a. **adolescence**
b. **adulthood**
c. **amniotic sac**
d. **catalase**
e. **childhood**
f. **embryo**
g. **fetus**
h. **infancy**
i. **menopause**
j. **menstrual cycle**
k. **menstruation**
l. **ovaries**
m. **ovulation**
n. **pregnancy**
o. **semen**
p. **sperm**
q. **testes**
r. **uterus**
s. **vagina**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. birth canal
2. male sex cells
3. egg-producing organs
4. release of egg from the ovary
5. nourishing fluid for sperm
6. ending of the menstrual cycle with age
7. sperm-producing organs
8. place where a fertilized egg develops into a baby
9. stores nutrients for the unborn baby
10. name for the unborn child the first two months

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. The embryo developed in the _______.
   a. oviduct
   b. ovary
   c. uterus
   d. vagina
2. The monthly process of egg release is called _______.
   a. fertilization
   b. ovulation
   c. menstruation
   d. puberty
3. The union of an egg and sperm is _______.
   a. fertilization
   b. ovulation
   c. menstruation
   d. puberty
4. The egg is fertilized in the _______.
   a. oviduct
   b. uterus
   c. vagina
   d. ovary
5. Mental and physical skills rapidly develop during _______.
   a. neonatal period
   b. infancy
   c. childhood
   d. adolescence
6. Puberty occurs during _______.
   a. childhood
   b. adulthood
   c. adolescence
   d. infancy
7. Sex characteristics common to males and females include _______.
   a. breasts
   b. increased muscles
   c. increased fat
   d. pubic hair
8. Growth of the skeleton and muscles stops during _______.
   a. childhood
   b. adolescence
   c. adulthood
   d. infancy
9. The period of development with three stages is _______.
   a. infancy
   b. adulthood
   c. adolescence
   d. childhood
10. The ability to reproduce begins at _______.
   a. adolescence
   b. adulthood
   c. childhood
   d. infancy

USING LAB SKILLS

11. The MINI-Lab on page 537 concerns the size of an embryo/fetus during development. Find and measure common household items that correspond to the fetus sizes. Example 6 months = 12 inch ruler. Set up a display of these items.
12. In the Activity on page 534, you learned how to interpret diagrams of the menstrual cycle. Use the diagram to explain how fraternal twins form.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Why are so many sperm released if only one is needed to fertilize an egg?
14. Why is semen necessary for sperm survival?
15. What is the purpose of the thickened uterine lining?
16. Explain the difference between identical and fraternal twins.
17. What features of a pregnant woman protect the developing child?

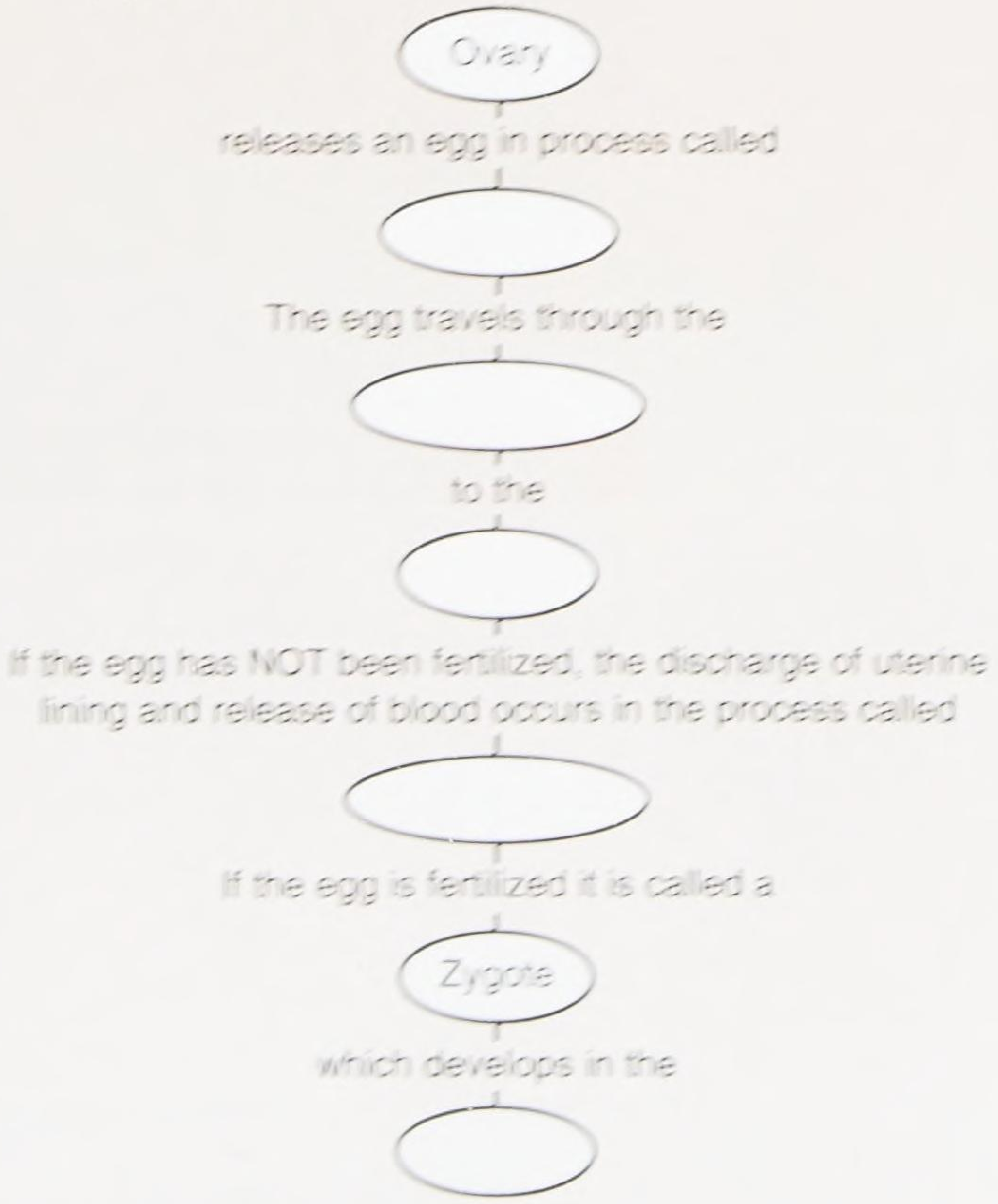
APPLY

18. Explain the similar functions of the ovaries and testes.
19. Identify the structure in which each process occurs: meiosis, ovulation, fertilization, and implantation.
20. Describe the structural differences between embryo and fetus.
21. What kind of cell division occurs as the zygote develops?
22. Describe one major change in each stage of human development.

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Classifying:** Classify each structure as female or male and internal or external: ovary, penis, scrotum, testes, uterus, vagina.
2. **Concept Mapping:** Fill in the concept map of egg release.


Ovary
releases an egg in process called
The egg travels through the
to the
If the egg has NOT been fertilized, the discharge of uterine lining and release of blood occurs in the process called
If the egg is fertilized it is called a
Zygote
which develops in the

3. **Hypothesizing:** Make a hypothesis about the effects of raising identical twins apart from each other.
4. **Making and Using Graphs:** Use the data to make a graph showing the day of development versus size of the embryo. When is the fastest period of growth?

Week after Fertilization	Size
3	3 mm
4	6 mm
6	12 mm
7	2 cm
8	4 cm
9	5 cm

5. **Sequencing:** Sequence the steps involved in the birth process.

PROJECTS

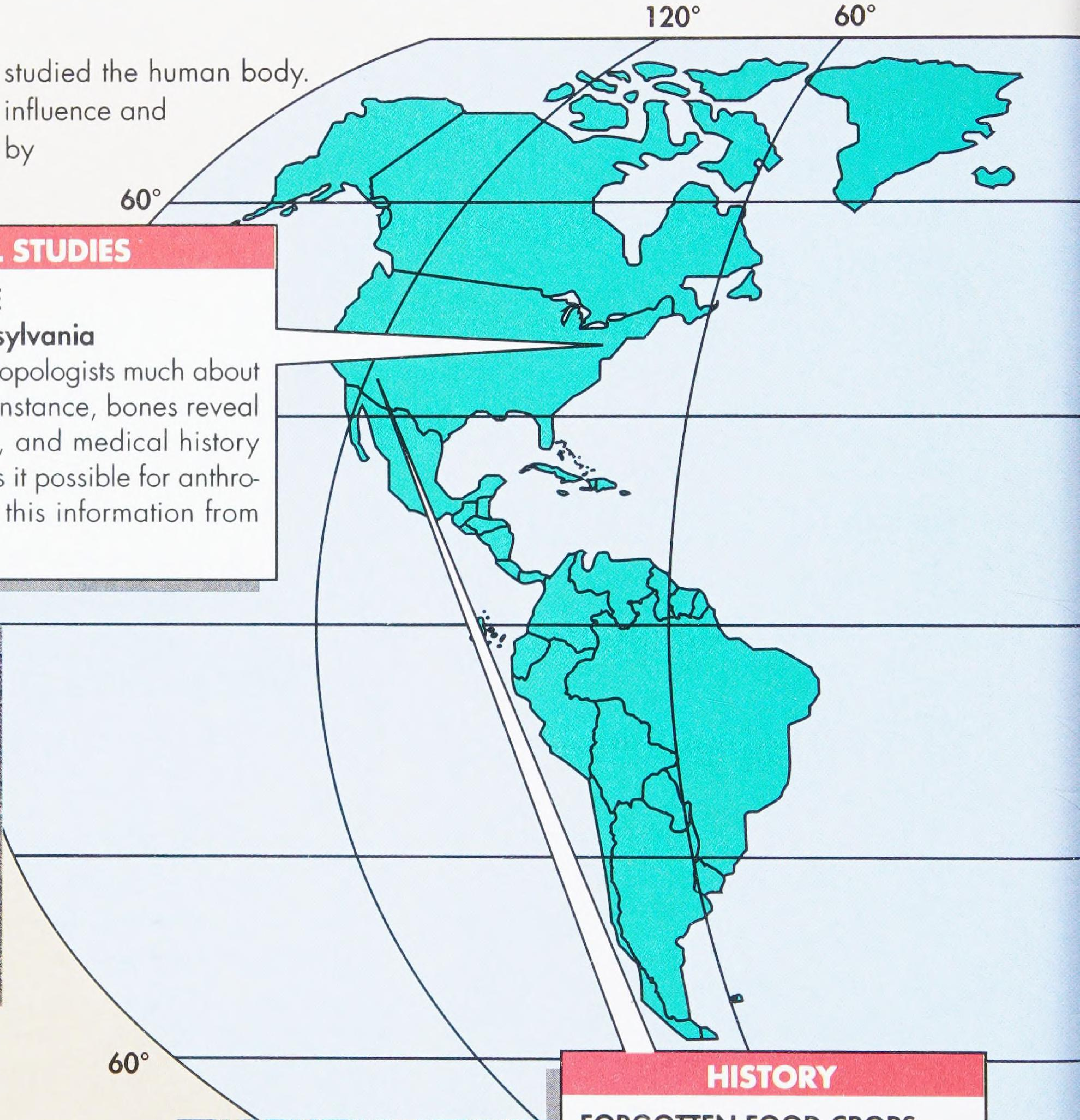
1. Find newspaper articles on the effects of smoking on the health of the developing embryo and newborns. Discuss this with your class.
2. Put a soft fruit or vegetable (plum, peach, tomato) into a self-sealing plastic bag filled with water. Use this model to observe how the fetus is protected from shock by the amniotic fluid.

UNIT 6

GLOBAL CONNECTIONS

The Human Body

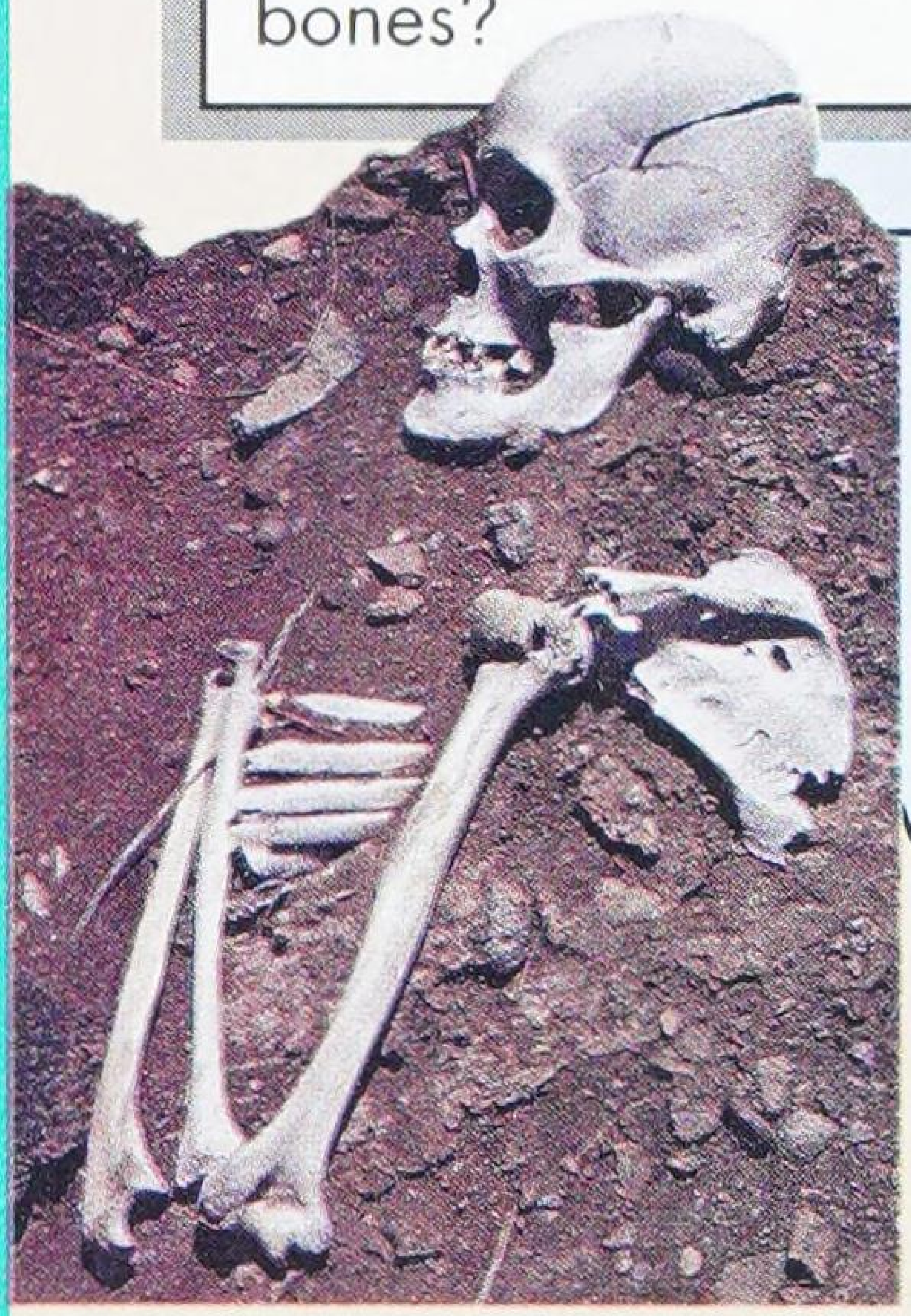
In this unit, you have studied the human body. Find out how humans influence and have been influenced by their world.



SOCIAL STUDIES

WRITTEN IN BONE
University of Pennsylvania

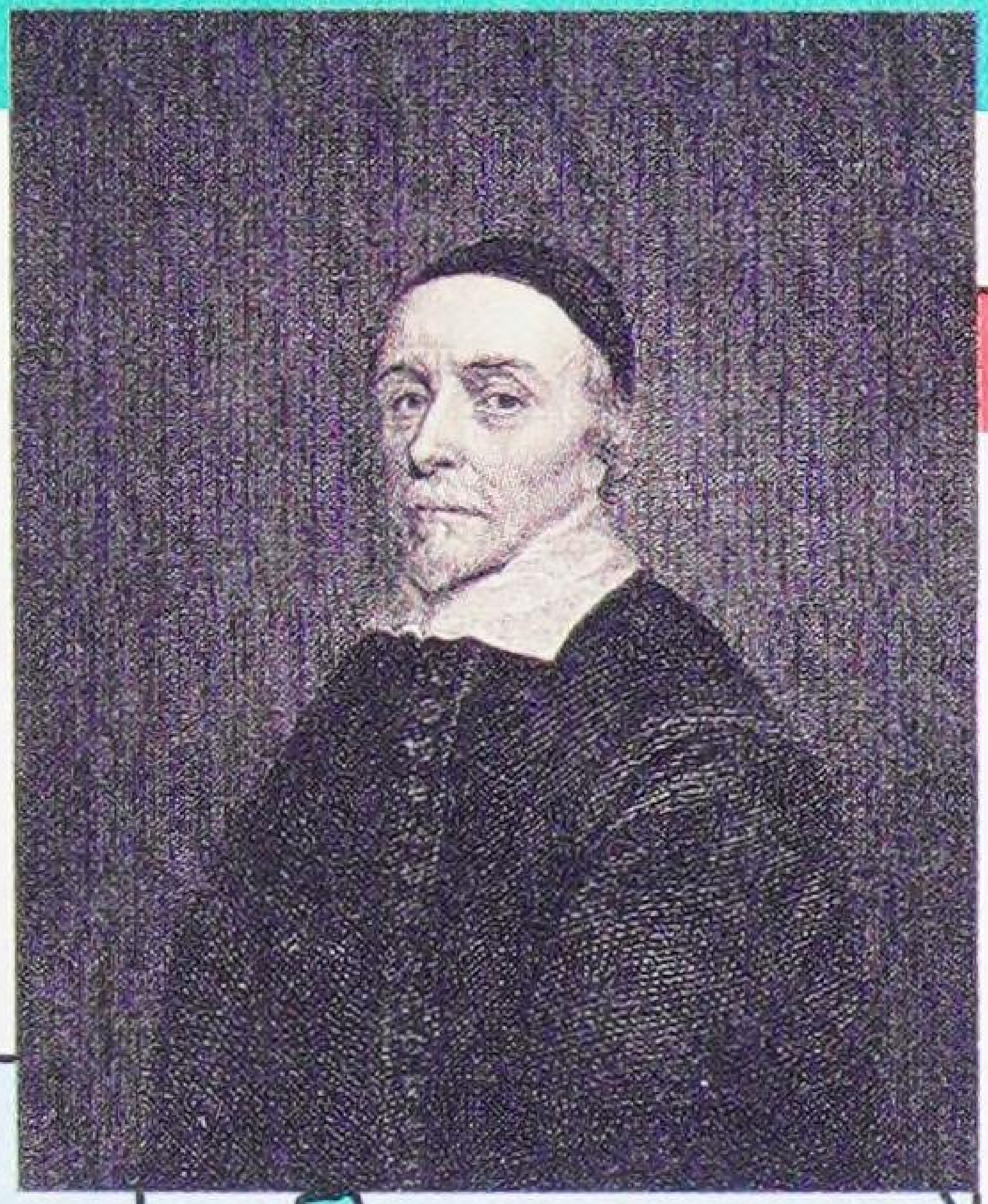
Bones can tell anthropologists much about an individual. For instance, bones reveal the age, sex, race, and medical history of a person. How is it possible for anthropologists to detect this information from bones?



HISTORY

FORGOTTEN FOOD CROPS
Colorado Springs, Colorado

Natural grains that native Americans once ate are being rediscovered. These food plants offer science some exciting solutions to world food problems. Why could these "new" old plants be important?



PHYSICS

THE MECHANICS OF BLOOD CIRCULATION

London, England

William Harvey, an English physician, proved that blood circulated as a result of the heart's pumping action. What is the path that blood travels through the body? Find out why the circulation of blood through the body is related to the study of physics.

ASTRONOMY

LOSS OF GRAVITY, LOSS OF MUSCLE

Moscow, Russia

Prolonged weightlessness causes muscles to shrink rapidly. Cosmonauts and astronauts also have trouble readjusting to gravity. What can space travellers do to maintain muscle strength?

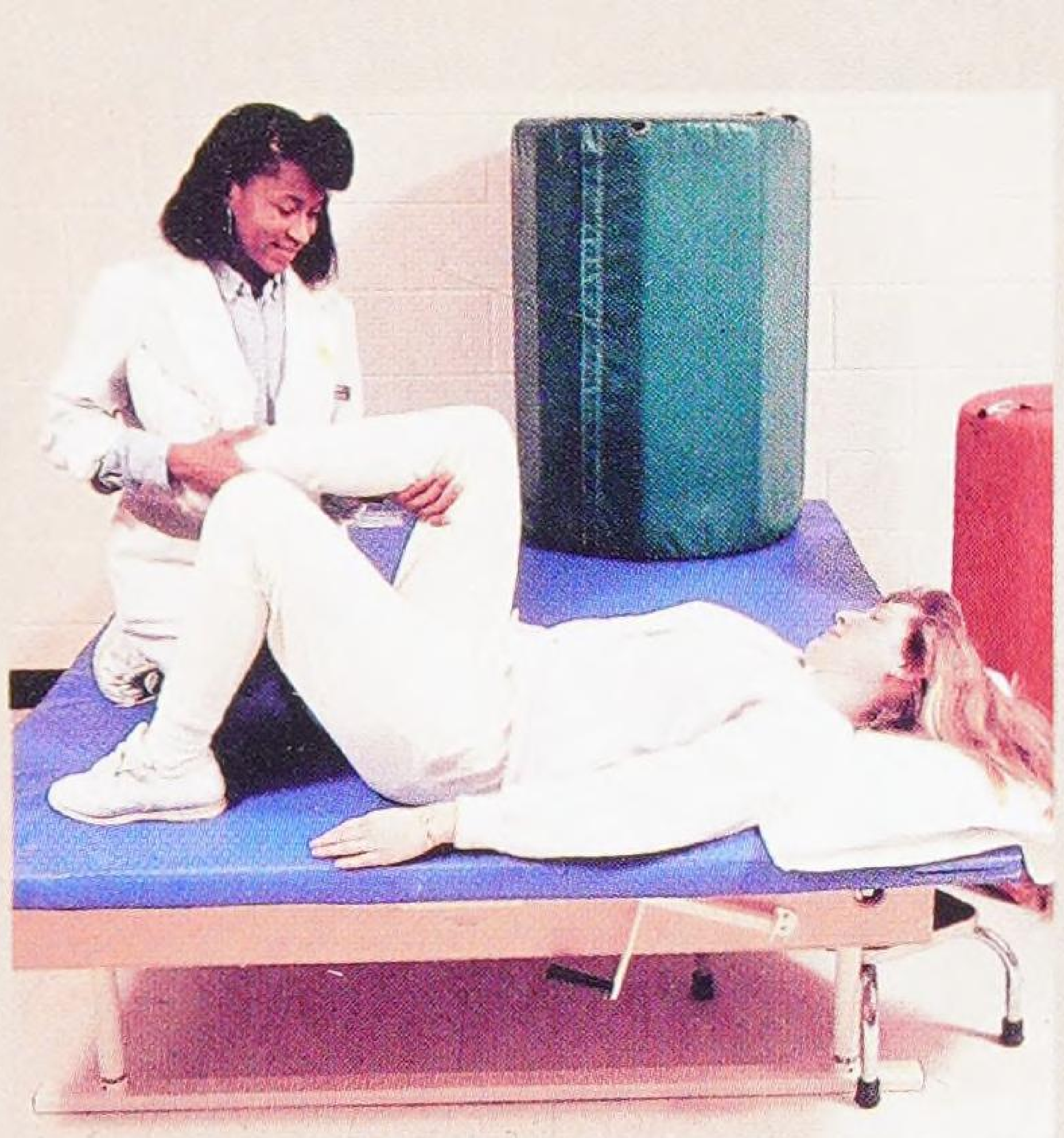
OCEANOGRAPHY

AMA, DEEP-WATER DIVERS

Hekura, Japan

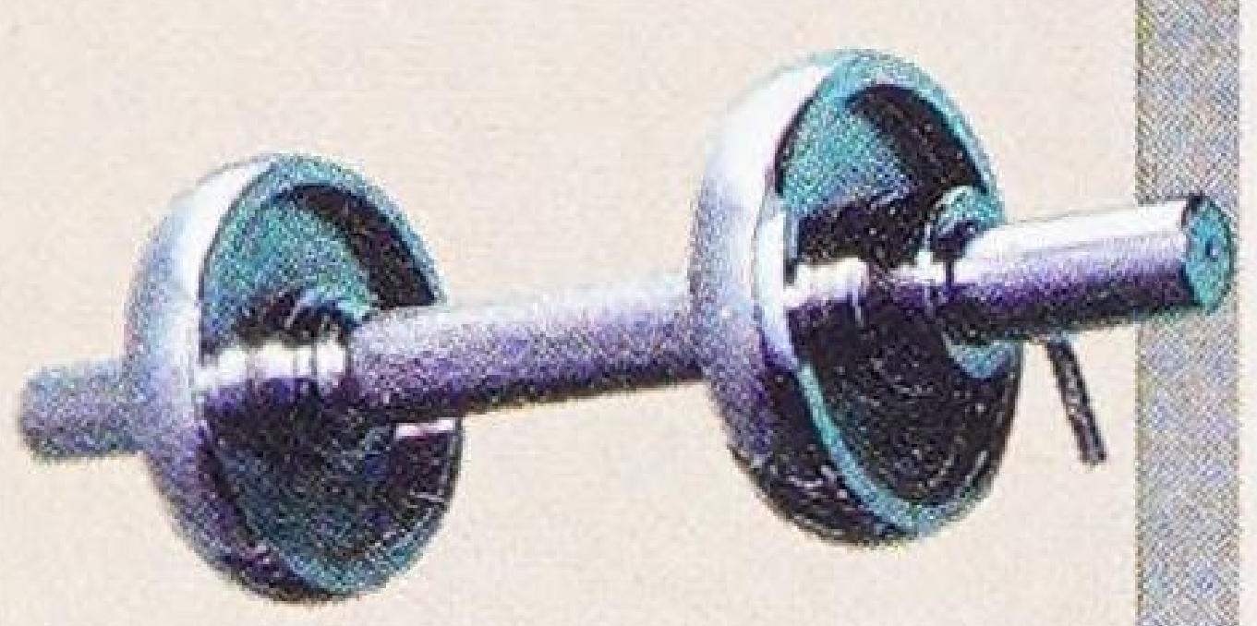
For 2000 years, Japanese women have been diving for shellfish. The Ama dive to depths as great as 75 feet without snorkels or air tanks. Read about the pearl divers in a library reference. Find out why more women practice this type of deep-water diving rather than men.

CAREERS



PHYSICAL THERAPIST

A *physical therapist* works with people who have had accidents, handicaps, arthritis, and heart disease. The patients range from newborn to elderly. Some physical therapists work with a wide range of problems. Others specialize, working in pediatrics, sports therapy, or neurology, as well as other specialties. Physical therapists need to be supportive of their patients, flexible, and physically strong. The work of the physical therapist is emotionally demanding but also rewarding. A physical therapist must have at least a bachelor of science degree. He or she will need to have courses in basic science, anatomy and physiology, as well as kinesiology, and a background in psychology.



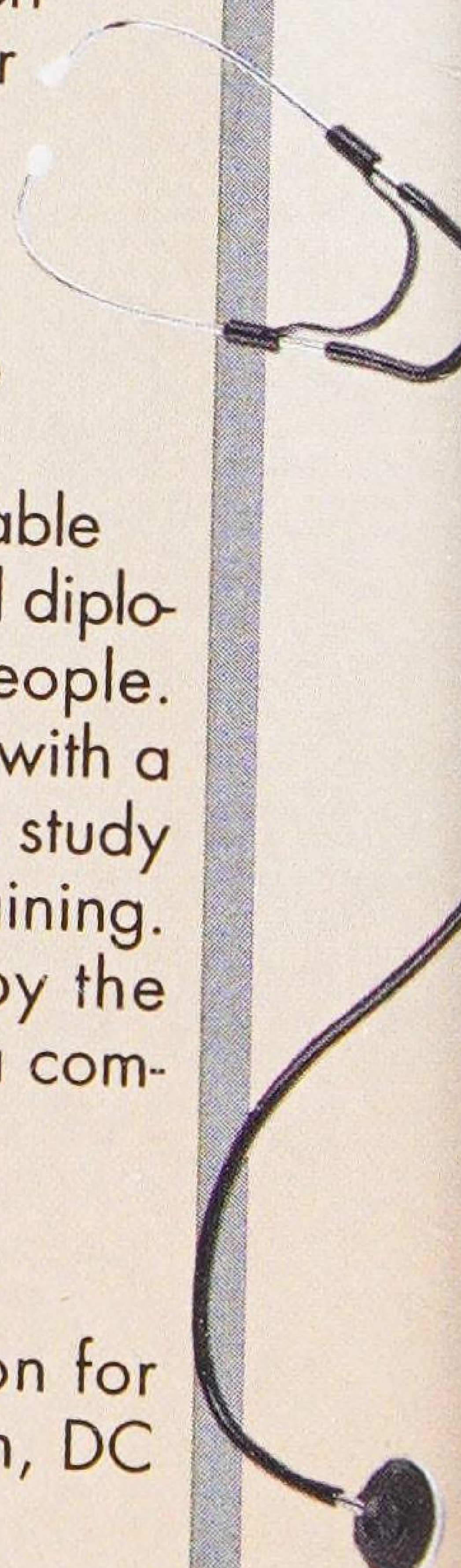
For Additional Information

Contact the American Physical Therapy Association, 1111 N. Fairfax St., Alexandria, VA 22314.

HOME HEALTHCARE AIDE

Home healthcare aides work with the elderly, disabled, or ill. The job of the healthcare aide varies from patient to patient. Schedules also vary so that a healthcare aide needs to be very adaptable. Many people need help with personal care, such as bathing and shampooing, either for a short time after a hospital stay, or for longer periods in the case of chronic illnesses. Aides check a patient's pulse and respiration, help with prescribed exercises, assist with medicines, and even prepare meals.

Home healthcare aides should be able to read and write and have a high school diploma, plus a deep interest in helping people. New laws require 75 hours of training with a combination of 16 hours of classroom study and 16 hours of supervised practical training. Training programs may be offered by the employing agency, the Red Cross, or a community college.



For Additional Information

Contact The National Association for Homecare, 519 C St. NE, Washington, DC 20002.

UNIT READINGS

- Golden, Frederic. "Clever Kanzi." *Discover*, March 1991, p. 20.
- Minsky, Marvin. "The Intelligence Transplant." *Discover*, Oct. 1989, p. 52.

Sula

by Toni Morrison

The following passage tells of two girlhood friends, Nel and Sula, who have been reunited after many years.

Nel alone noticed the peculiar quality of the May that followed the leaving of the birds. It had a sheen, a glimmering as of green, rain-soaked Saturday nights (lit by the excitement of newly installed street lights); of lemon-yellow afternoons bright with iced drinks and splashes of daffodils. It showed in the damp faces of her children and the river-smoothness of their voices. Even her own body was not immune to the magic. She would sit on the floor to sew as she had done as a girl, fold her legs up under her or do a little dance that fitted some tune in her head. There were easy sun-washed days and purple dusks in which Tar Baby sang "Abide With Me" at prayer meetings, his lashes darkened by tears, his silhouette limp with regret against the whitewashed walls of Greater Saint Matthew's. Nel listened and was moved to smile. To smile at the sheer loveliness that pressed in from the windows and touched his grief, making it a pleasure to behold.

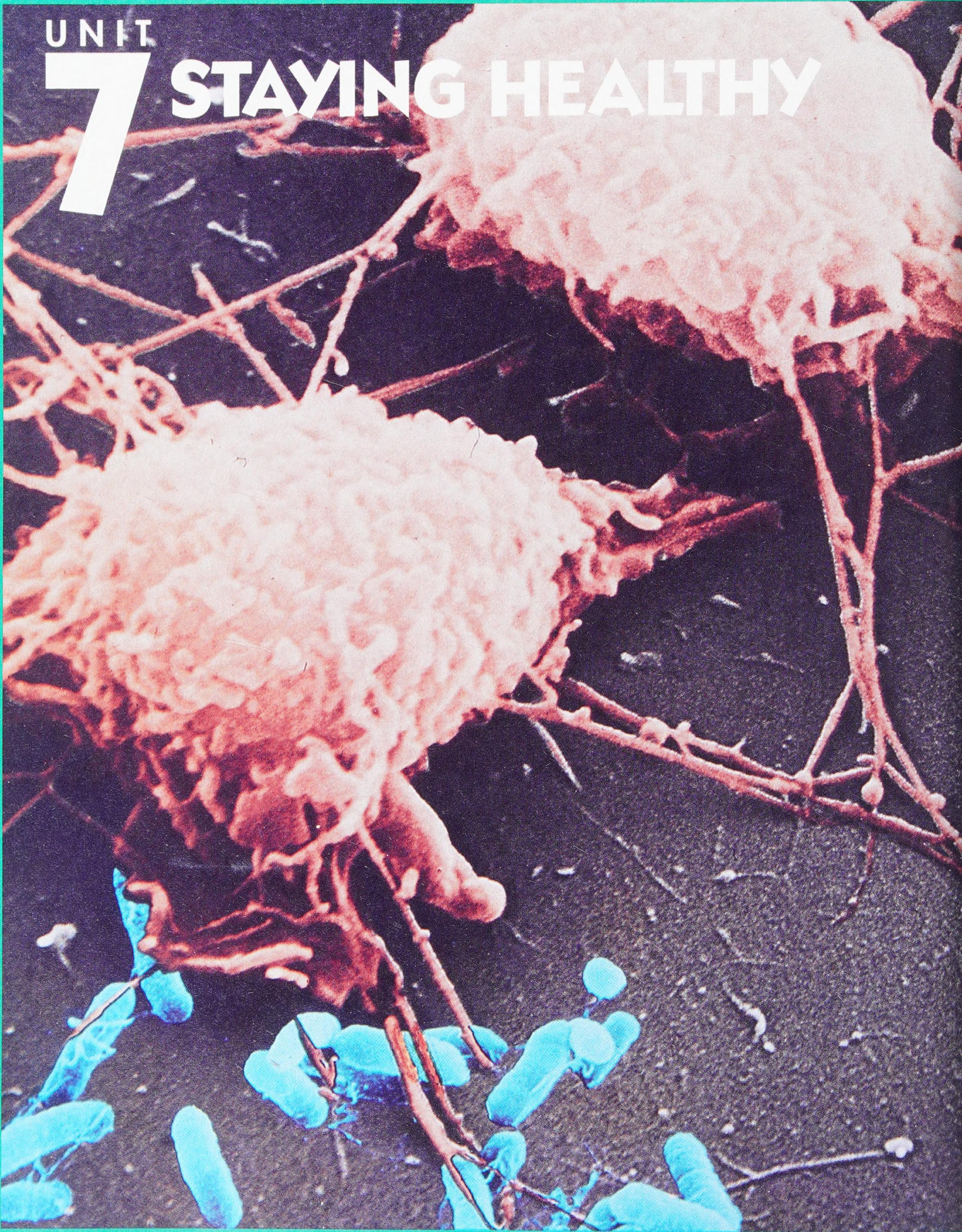
Author Toni Morrison

Although it was she alone who saw this magic, she did not wonder at it. She knew it was all due to Sula's return to the Bottom. It was like getting the use of an eye back, having a cataract removed. Her old friend had come home. Sula. Who made her laugh, who made her see old things with new eyes, in whose presence she felt clever, gentle and a little raunchy. Sula, whose past she had lived through and with whom the present was a constant sharing of perceptions. Talking to Sula had always been a conversation with herself. Was there anyone else before whom she could never be foolish? In whose view inadequacy was a mere idiosyncrasy, a character trait rather than a deficiency? Sula never competed; she simply helped others define themselves. Other people seemed to turn their volume on and up when Sula was in the room. More than any other thing, humor returned. She could listen to the crunch of sugar underfoot that the children had spilled without reaching for the switch; and she forgot the tear in the living-room window shade.

In Your Own Words

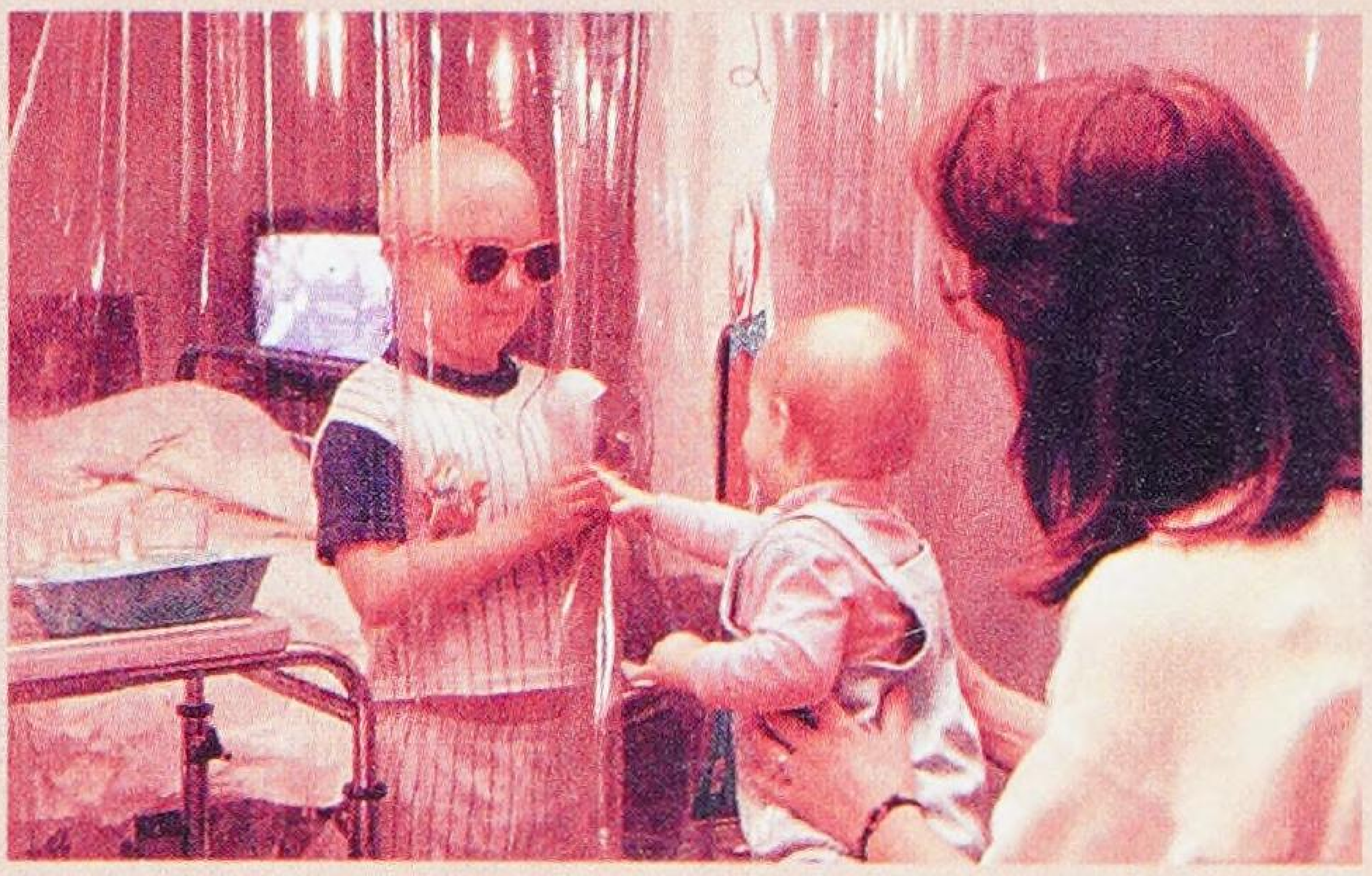
▶ Scientists and doctors often notice the effect of mental attitude on the human body. In this passage, you can see the effect Sula's return had on her friend, Nel. Think of an event in your own life that has changed your outlook either for better or worse. How did you feel after it? What physical changes did you feel? Write a short story telling of this event and how it affected you.

UNIT 7 STAYING HEALTHY



What's Happening Here?

The mighty macrophage puts forth tendril-like extensions as it reaches out to snag bacterial cells that daily attack the fortress of your body. Constantly on guard, these large white blood cells patrol the body, slipping between cells in capillary walls to sweep up invaders that threaten your health. Your body is equipped with a variety of defenses that maintain your health even though you remain unconscious of their activity. The child in the smaller photograph is very conscious of his defense system. Lacking a natural defense system, he depends on the walls of his artificial environment to protect him from assault by disease-causing agents.



UNIT CONTENTS

Chapter 24 Immunity
Chapter 25 Facts about Drugs

CHAPTER

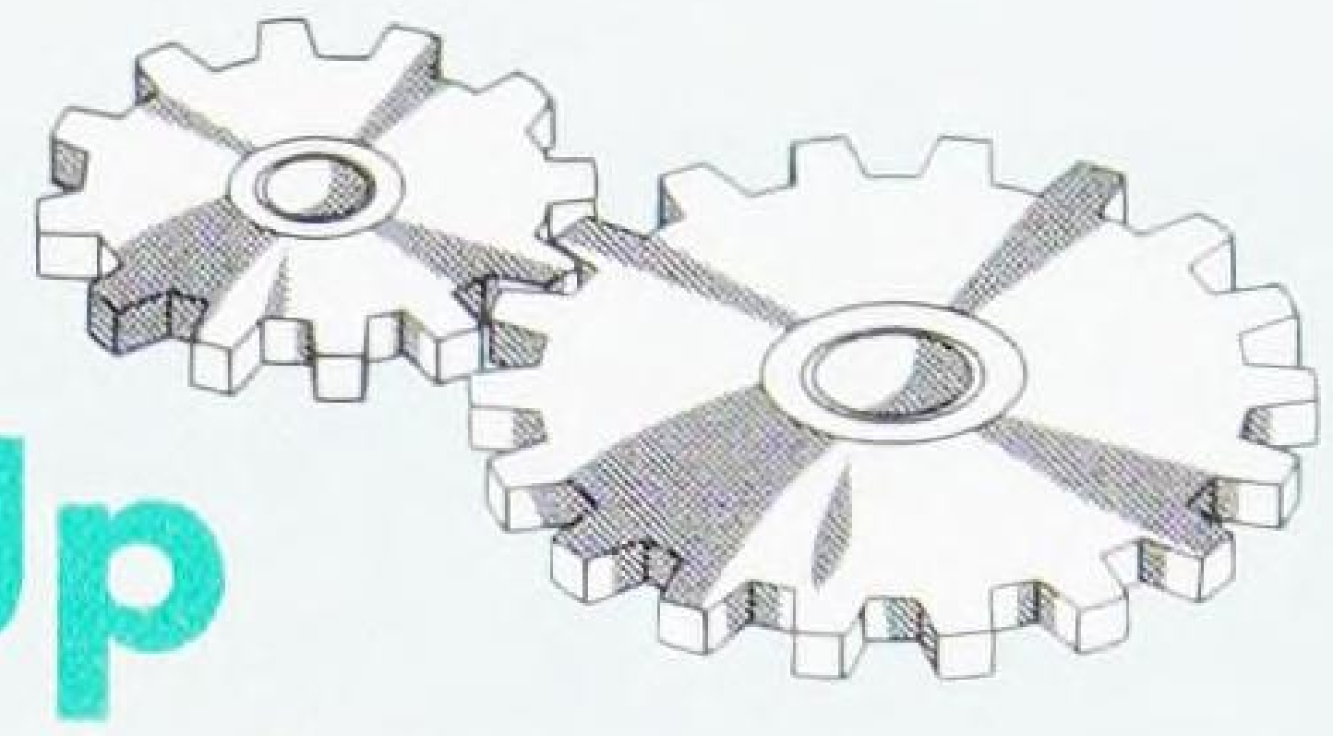
24 Immunity

Aaahhh-choooo! Does pollen make you sneeze? Have you noticed that when one person in your class gets a cold, others soon have it too? Allergies and colds are examples of your body's response to substances and organisms in the environment.

FIND OUT!

Do this activity to see how disease-causing organisms can be spread.

Work with a partner. Place a drop of peppermint or lemon food flavoring on a cotton ball. Pretend that the flavoring is a mass of cold viruses. Next, rub the cotton ball in the shape of an X over the palm of your right hand and let it dry. Can you smell the flavoring? Now, shake hands with a classmate. **Hypothesize** how some diseases can be spread. *Design an experiment* to determine how many persons could be infected by the peppermint "virus."



Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 24-1 The Nature of Disease
- Discovering Disease
- Keeping Clean
- Communicable Diseases
- Sexually Transmitted Diseases

Section 24-2 Your Immune System
- Natural Defenses
- Specific Defenses
- HIV and Your Immune System

Section 24-3 Science & Society Preventing Disease
- Guarding Against Disease

Section 24-4 Noncommunicable Disease
- Chronic Disease
- Cancer
- Allergies

Previewing Science Skills

- In the **Skill Builders,** you will recognize cause and effect, compare and contrast, and make and use tables.
- In the **Activities,** you will experiment, hypothesize, and analyze data.
- In the **MINI-Labs,** you will test and observe, and calculate and graph results.

What's next?

You have just seen how disease can be spread from person to person. Discover ways that disease can be spread by bacteria and viruses and what steps you and your body take to prevent this from happening. You will also learn about diseases and disorders that are caused by genetic, metabolic, and life-style factors.

24-1 The Nature of Disease

New Science Words

pasteurization
disinfectant
antiseptic
communicable disease
sexually transmitted diseases (STDs)

Objectives

- Describe the work of Pasteur, Koch, and Lister in the discovery and prevention of disease.
- List diseases caused by viruses and bacteria.
- Discuss sexually transmitted diseases (STDs), their causes and treatment.

In Your JOURNAL

What is the relationship between yellow fever and the building of the Panama Canal? Write a report **in your Journal** about the effect of yellow fever on the construction of the Panama Canal.

Discovering Disease

"Ring around the rosie, A pocket full of posies,
Ashes, Ashes, We all fall down."

Do you know that this rhyme is more than 600 years old? The rhyme is thought to be about a disease called the Black Death or the Plague. In the thirteenth century, the Plague killed one-fourth of the people in Europe. "Ring around the rosie" was a symptom of the disease—a ring around a red spot on the skin. People carried a pocket full of flower petals ("posies") and spices to keep away the stench of dead bodies. But still, 25,000,000 people "all fell down," dead from this terrible disease.

Today we know that diseases are caused by viruses and by harmful bacteria known as pathogens, and not by some fault in a person's behavior as was once believed.

Louis Pasteur, a French chemist, was the first to discover that harmful bacteria could cause disease. He

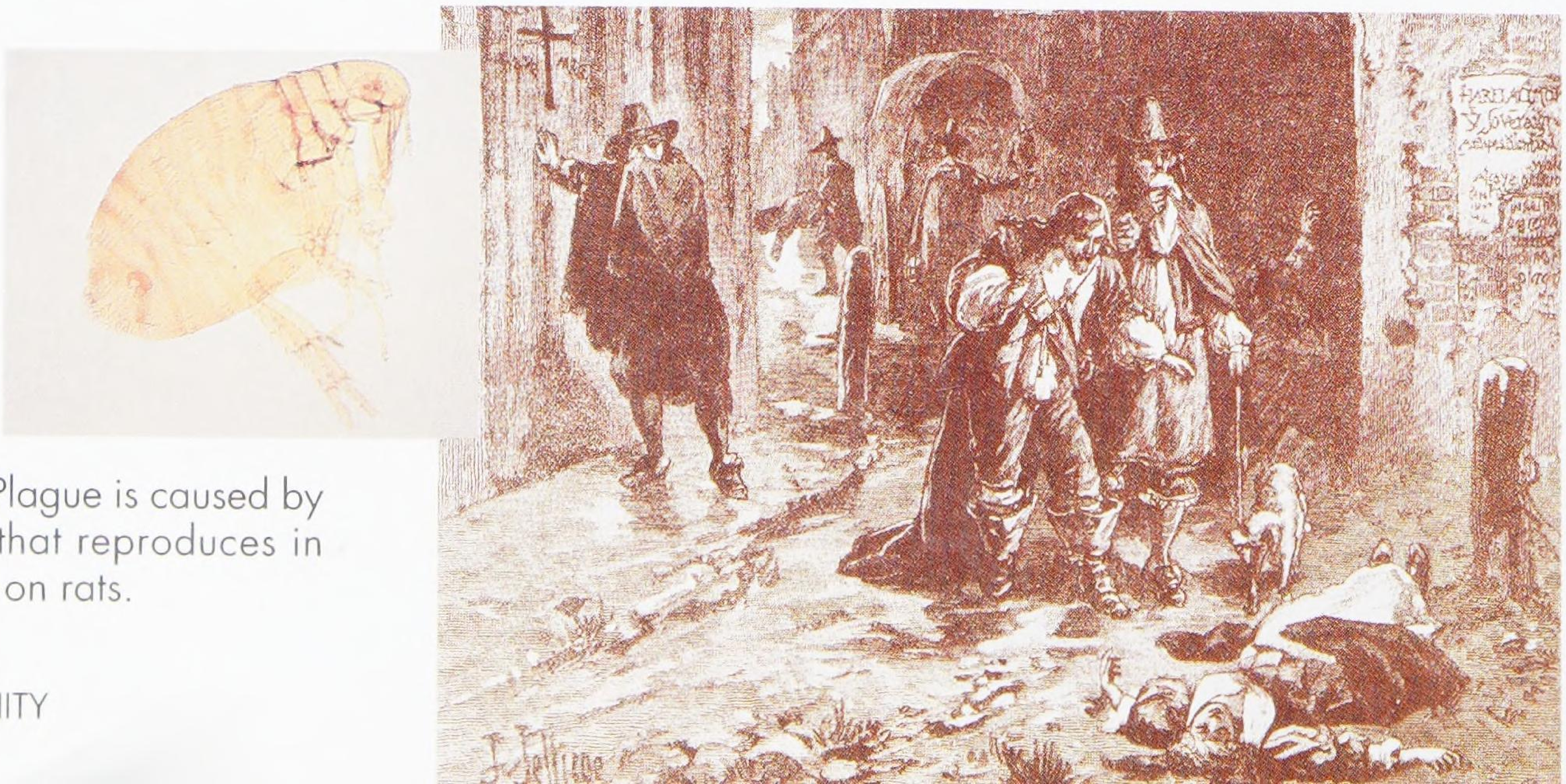


Figure 24-1. Plague is caused by a bacterium that reproduces in fleas that live on rats.

developed a method of using heat to kill pathogens. **Pasteurization,** named for him, is the process of heating food to a temperature that kills most bacteria. Pasteur's work began the science of bacteriology.

Being able to tell *which* organism caused a disease was a problem. It was a German doctor, Robert Koch, who first developed a way to isolate and grow, or culture, just one type of bacteria at a time. Koch developed a set of rules to be used for figuring out which organism caused a particular disease. These rules are:

1. In every case of a particular disease, the organism thought to cause the disease must be present.
2. The organism has to be separated from all other organisms and grown in a pure culture.
3. When the organism from the pure culture is injected into a test animal, it must cause the original disease.
4. Finally, when the suspect organism is removed from the test animal and cultured again, it must be compared with the original organism to see if they are the same. Only when they match can you say that that organism is the pathogen that causes that disease.

Keeping Clean

Do you make it a habit to wash your hands and clean your fingernails? Into the late 1800s, doctors regularly operated in their street clothes and with their bare hands. More patients died than survived as a result of surgery. Joseph Lister, an English surgeon, was horrified. He recognized the relationship between the infection rate and cleanliness in surgery. Lister dramatically reduced deaths among his surgical patients by washing their skin and his hands before surgery. Lister used a disinfectant, but today antiseptics are used on people. A **disinfectant** kills pathogens on objects such as instruments, floors, toilets, and bathtubs. An **antiseptic** kills pathogens on skin and prevents them from growing there for sometime after. Today doctors wash their hands often with antiseptic soaps to keep from spreading pathogens from person to person. However, even with the use of disinfectants, some diseases could not be controlled. In the late 1800s and early 1900s, viruses were discovered.

Because of the work of these early scientists, and many others who followed, more is understood about the cause and control of disease.

Did You Know?

Researchers at an institute in England spent forty years trying to find a cure for the common cold. The institute is now closed due to a lack of success.

Figure 24-2. Antiseptics and strict surgical methods have made operations safer than they once were.

MINI-Lab

Are bacteria present in food?

Methylene blue is a dye used to detect bacteria. The faster the color fades when we add the dye to a substance, the more bacteria the substance contains. Use the samples provided by your teacher to compare the amount of bacteria in each. Label four test tubes 1, 2, 3, and 4. Fill the first three half full with the substance to be tested. Fill the fourth with water. Add 20 drops of methylene blue to each test tube. Add 2 drops of mineral oil to each tube. Place the tubes into a warm water bath. Write down the time, and observe. Record and *compare* how long it takes each tube to lose its color. *Conclude* why it is important to eat and drink only the freshest foods.

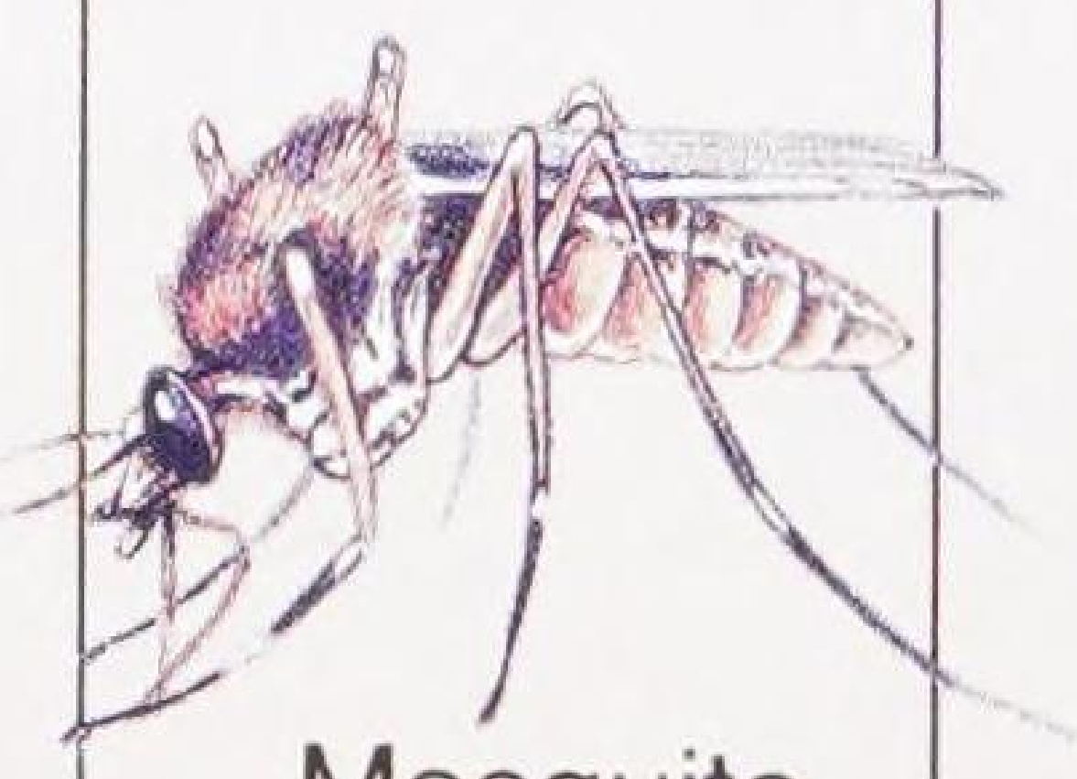
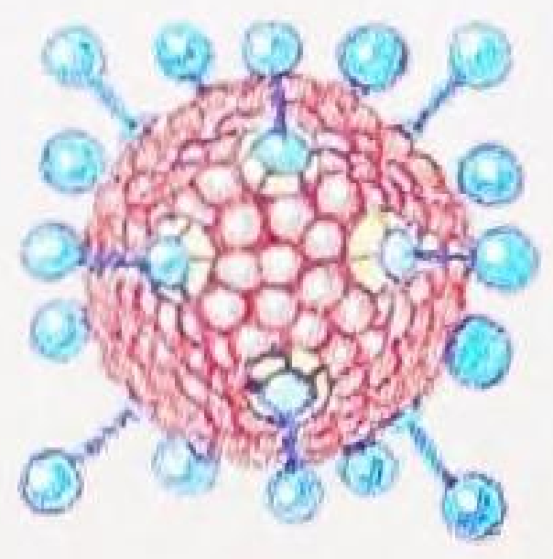
Communicable Diseases

Have you ever shared a soft drink with a friend? Did you both use the same straw? Sharing eating or drinking implements is one way that many diseases are spread from person to person. A disease that is spread, or transmitted, from one organism to another is a **communicable disease.**

What causes a communicable disease? Communicable diseases are caused by agents such as viruses, pathogenic bacteria, protists, and fungi. Some diseases caused by these agents are given in Table 24-1.

Table 24-1

DISEASES AND THEIR AGENTS

Bacteria	Protists	Fungi	Viruses
Tetanus Tuberculosis Typhoid fever Strep throat Pink eye Bacterial pneumonia Plague	Malaria Sleeping sickness  Mosquito	Athlete's foot Ringworm  Virus	Colds Influenza AIDS Measles Mumps Yellow fever Polio Smallpox Viral pneumonia

Communicable diseases are spread through water and air, on food, by contact with contaminated objects, and by vectors. City water systems and swimming pools add chlorine to prevent disease. Many diseases are spread through air. When you have a cold and sneeze, you hurl thousands of virus particles through the air. Each time you turn a doorknob, or press the button on a water fountain at school, your skin comes in contact with bacteria and viruses. Finally, some of the most dangerous diseases are transmitted by sexual contact.

Examples of vectors that spread disease are rats, mice, flies, fleas, mosquitoes, birds, and cats and dogs. Six hundred years ago, the bacterium that causes Plague was spread by fleas that lived on rats.

The spread of communicable diseases is closely watched by agencies in every country. In the United States, the Centers for Disease Control (CDC) monitors the spread of diseases throughout the country. The CDC also watches for diseases brought into the country.

Connect to...

Chemistry

Many chemical disinfectants lower the surface tension of bacteria, allowing the chemical to be more easily absorbed. Find out what surface tension is. What makes a disinfectant effective?

Sexually Transmitted Diseases

Diseases transmitted from person to person during sexual contact are called **sexually transmitted diseases (STDs).** You can become infected with an STD by having sex with an infected person. STDs are caused by both viruses and bacteria.

In Chapter 8, you learned that HIV is a latent virus that can exist in blood and body fluids. You can contract AIDS by having sex with an HIV-infected person, or by sharing an HIV-contaminated needle used to inject drugs. AIDS is also transmitted by contaminated blood transfusions, and a pregnant female with AIDS may infect her child when the virus passes through the placenta or when nursing after birth. There is no vaccine to prevent AIDS and no medication to cure it. In the next section, more information will be given on how AIDS breaks down the immune system.

Genital herpes causes painful blisters on the sex organs. Herpes can be transmitted by an infected mother to her child during birth. The herpes virus, also a latent virus, hides in the body for long periods and then reappears suddenly. There is no cure for herpes, and there is no vaccine to prevent it.

Gonorrhea and chlamydia are STDs caused by bacteria that may not produce any symptoms. When symptoms do appear, they may include painful urination, genital discharge, and sores. Penicillin and other antibiotics are used to treat these diseases. If left untreated, either disease can cause sterility, the inability to reproduce.

Table 24-2

STDs	
Agent	**Disease**
Bacteria	Gonorrhea Chlamydia Syphilis
Viruses	Genital Herpes AIDS Genital warts

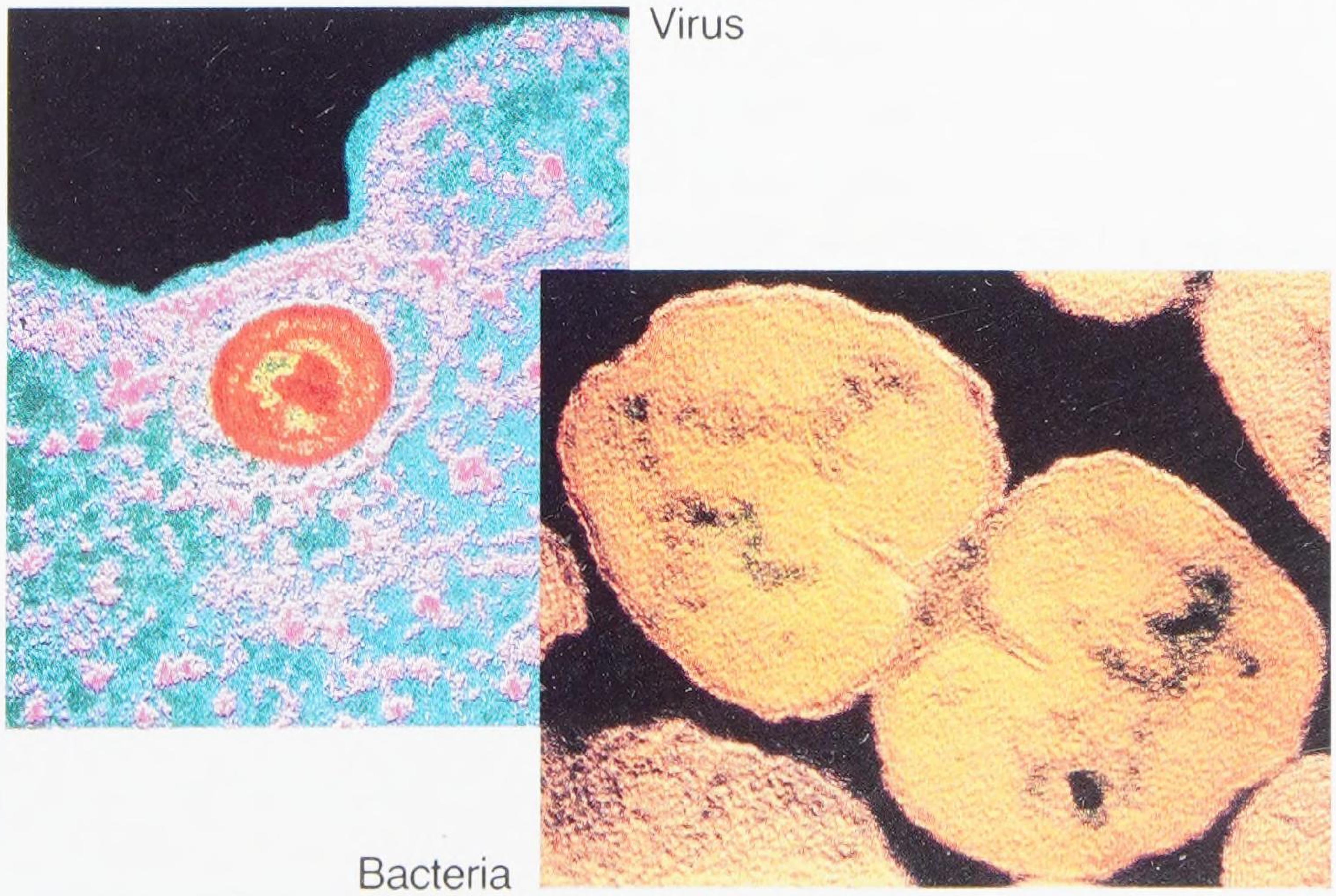


Figure 24-3. Sexually transmitted diseases are caused by certain viruses and bacteria.

Amoxicillin for Oral Suspension, USP
250 mg per 5 mL
100 mL bottle

Figure 24-4. Penicillin is used to treat many diseases including some STDs.

Syphilis has several stages. In stage 1, a sore apears on the mouth or genitals that lasts 10 to 14 days. Stage 2 may involve a rash, a fever, and swollen lymph glands. During stage 3, these symptoms then may also disappear. The victim often believes that the disease has gone away, but it hasn't. In Stage 4, syphilis may infect the cardiovascular and nervous systems. At this point, it is too late to treat syphilis. Nerve damage and death may result. Syphilis can be treated and cured with antibiotics only in the early stages.

Sexually transmitted diseases are difficult to treat. For years, penicillin was used to treat syphilis. However, the organism that causes syphilis has become resistant to the antibiotic in some persons. In 1989, an artificial form of penicillin was made in the laboratory that may be effective against the disease.

SECTION REVIEW

1. How did the discoveries of Pasteur, Koch, and Lister help in the battle against disease?
2. List a communicable disease caused by a virus, a bacterium, a protist, and a fungus.
3. What are the four stages of syphilis?
4. **Apply:** In what ways does Koch's procedure follow the scientific method?
5. **Connect to Physics:** Find out how ultraviolet light is used to disinfect.

MINI-Lab

How fast do bacteria reproduce?

Bacteria divide every 20 minutes. If your body did not defend itself, it would be invaded by thousands of bacteria in just a few hours. You can't believe that? Then make a chart like the one below. Complete it to the fifth hour. How many bacteria will there be after five hours? *Graph* your data. Can you see why it is important to take antibiotics promptly if you have an infection?

Time	Number of Bacteria
0 hours 0 minutes	1
20 minutes	2
40 minutes	4
1 hour 0 minutes	8
20 minutes	
40 minutes	

Skill Builder

Recognizing Cause and Effect

How is not washing your hands related to the spread of disease? If you need help, refer to Recognizing Cause and Effect in the Skill Handbook on page 683.

Your Immune System 24-2

Objectives

- ▶ Explain the natural defenses your body has against disease.
- ▶ Describe differences between active and passive immunity.
- ▶ Explain how HIV affects the immune system.

New Science Words

immune system
antigens
antibody
active immunity
passive immunity
lymphocytes

Natural Defenses

A healthy body is like a well-equipped fortress. Your **immune system** is a complex group of defenses that your body has to fight disease. It is made up of cells, tissues, organs, and body systems that fight bacteria, viruses, harmful chemicals, and cancer cells.

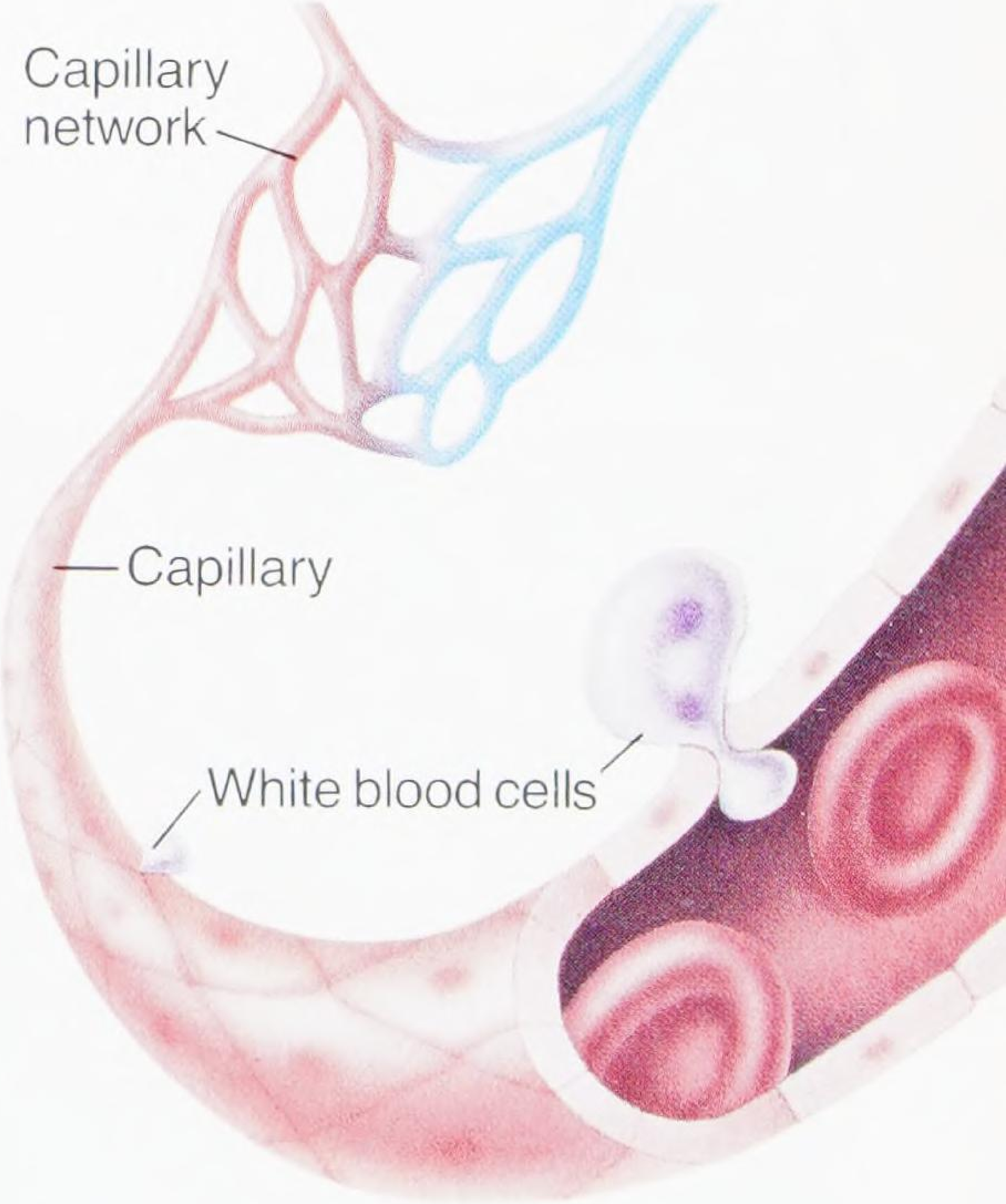
In Section 24-1, harmful bacteria were discussed for their disease-causing properties. However, most bacteria do not cause disease. Millions of helpful bacteria live on your skin and give you your first line of defense by killing many harmful types of bacteria. Disease-causing bacteria enter your body through breaks in your skin. Even then, your body is not defenseless. It mobilizes a series of defenses against disease-causing intruders.

Several other body systems maintain health. Your circulatory system contains white blood cells that engulf and digest foreign organisms and chemicals. These white blood cells constantly patrol the body, sweeping up and digesting bacteria that manage to get into the body. They slip between cells in the walls of capillaries to destroy bacteria around cells. When the white cells cannot destroy the bacteria fast enough, a fever may develop. But fever generally also helps to fight the pathogen.

Your respiratory system contains cilia and mucus to trap pathogens. When you cough, you expel trapped bacteria. In the digestive system, enzymes in the stomach, pancreas, and liver destroy pathogens. Hydrochloric acid in your stomach kills bacteria that enter your body on food that you eat.

All of these processes are general defenses that work to keep you disease-free. But if you do get sick, your body has another line of defense in the form of active and passive immunity.

Figure 24-5. White blood cells leave capillaries and engulf harmful bacteria in surrounding tissues.



Specific Defenses

What is an antigen?

When your body fights disease, it is really battling proteins or chemicals that don't belong there. Proteins and chemicals that are foreign to your body are called **antigens.** When your immune system recognizes a foreign protein or chemical, it forms specific antibodies. An **antibody** is a substance made by an animal in response to a specific antigen. The antibody binds up the antigen, making it harmless. Antibodies help your body build defenses in two ways, actively and passively. **Active immunity** occurs when your body makes its own antibodies in response to an antigen. **Passive immunity** occurs when antibodies, which have been produced in another animal, are introduced into the body.

Active Immunity

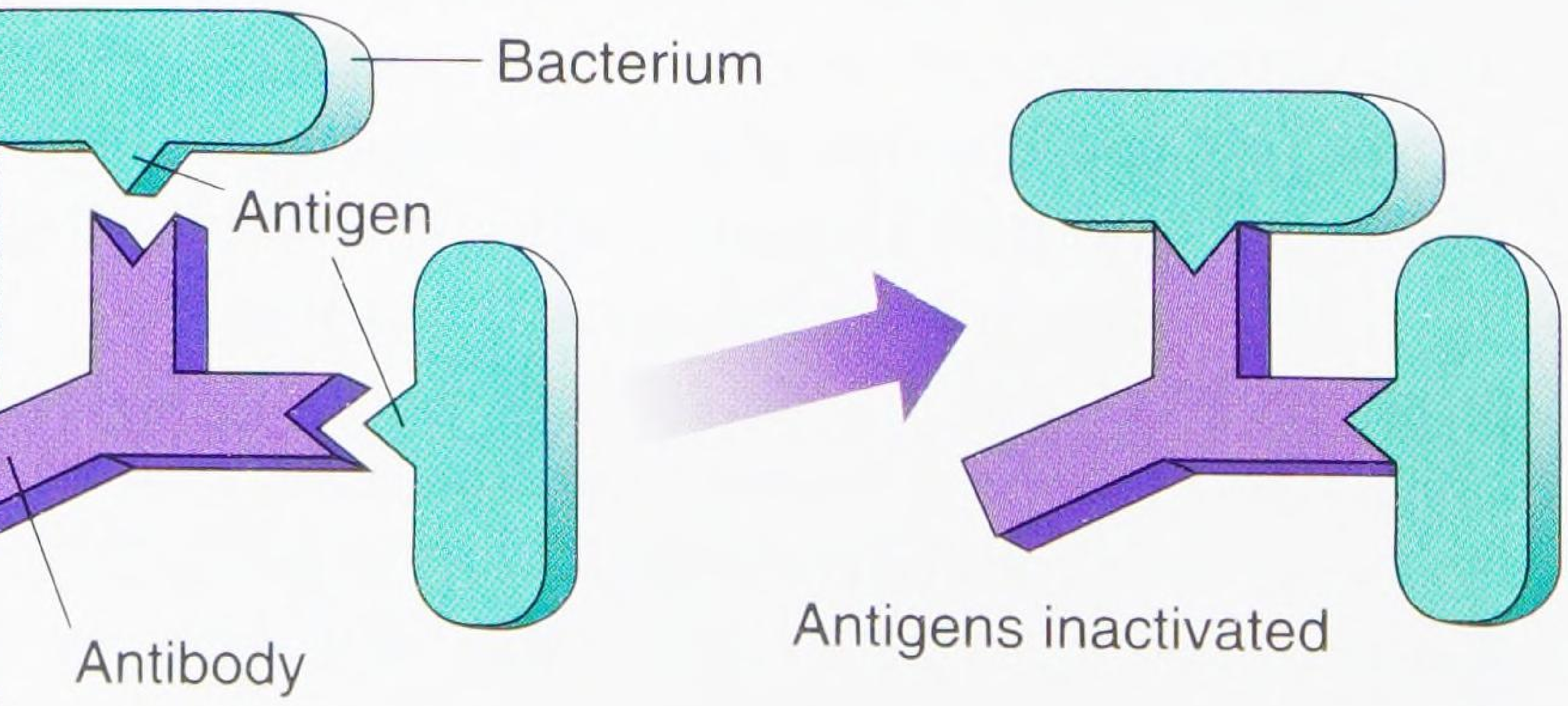
If your body is invaded by a pathogen, it immediately starts to make antibodies to inactivate the antigen. Once enough antibodies form, you get better. These antibodies stay in your blood on duty, becoming active when you again encounter the disease. Under these conditions, your body has active immunity to a particular disease.

Another way to develop active immunity to a particular disease is to be inoculated with a vaccine. A vaccine gives you active immunity against a disease without you having to get the disease first. For example, suppose a vaccine for measles is injected into your body. Your body to forms antibodies against the measle antigen. If you later encounter the virus, antibodies necessary to fight that virus are already in your bloodstream ready to destroy the pathogen. Antibodies that immunize you against one virus may not guard against a different virus. As you grow older, you will be exposed to many more types of viruses and will build a separate immunity to each one.

EcoTip

Reduce the use of pesticides in your home and around your garden. Many cause harmful effects on the immune systems of people.

Figure 24-6. Vaccines containing weakened antigens cause the body to make antibodies.



Passive Immunity

How is passive immunity different from active immunity? Passive immunity comes from several sources. As a newborn, you were a bundle of passive immunity. You were born with all the antibodies that your mother had in her blood. However, these antibodies stayed with you only a few months. Passive immunity does not last as long as active immunity. Newborn babies loose their passive immunity in a few months. Then they are vaccinated to develop their own immunity.

Tetanus is an example. Tetanus toxin is produced by a bacterium in soil. The toxin paralyzes muscles. Death can occur by suffocation when the muscles that control breathing become paralyzed. Tetanus antitoxin is produced in horses when they respond to injections of the tetanus antigen. Samples of antibodies made by horses are injected into humans. These antibodies provide limited immunity. Booster shots are needed throughout life, especially in the case of puncture wounds.

In Your JOURNAL

Select a disease from this list: diphtheria, pertussis, tetanus. Using library references, write **in your Journal** about what causes the disease; what its symptoms are; and how technological advances have developed treatment or prevention of the disease.

TECHNOLOGY

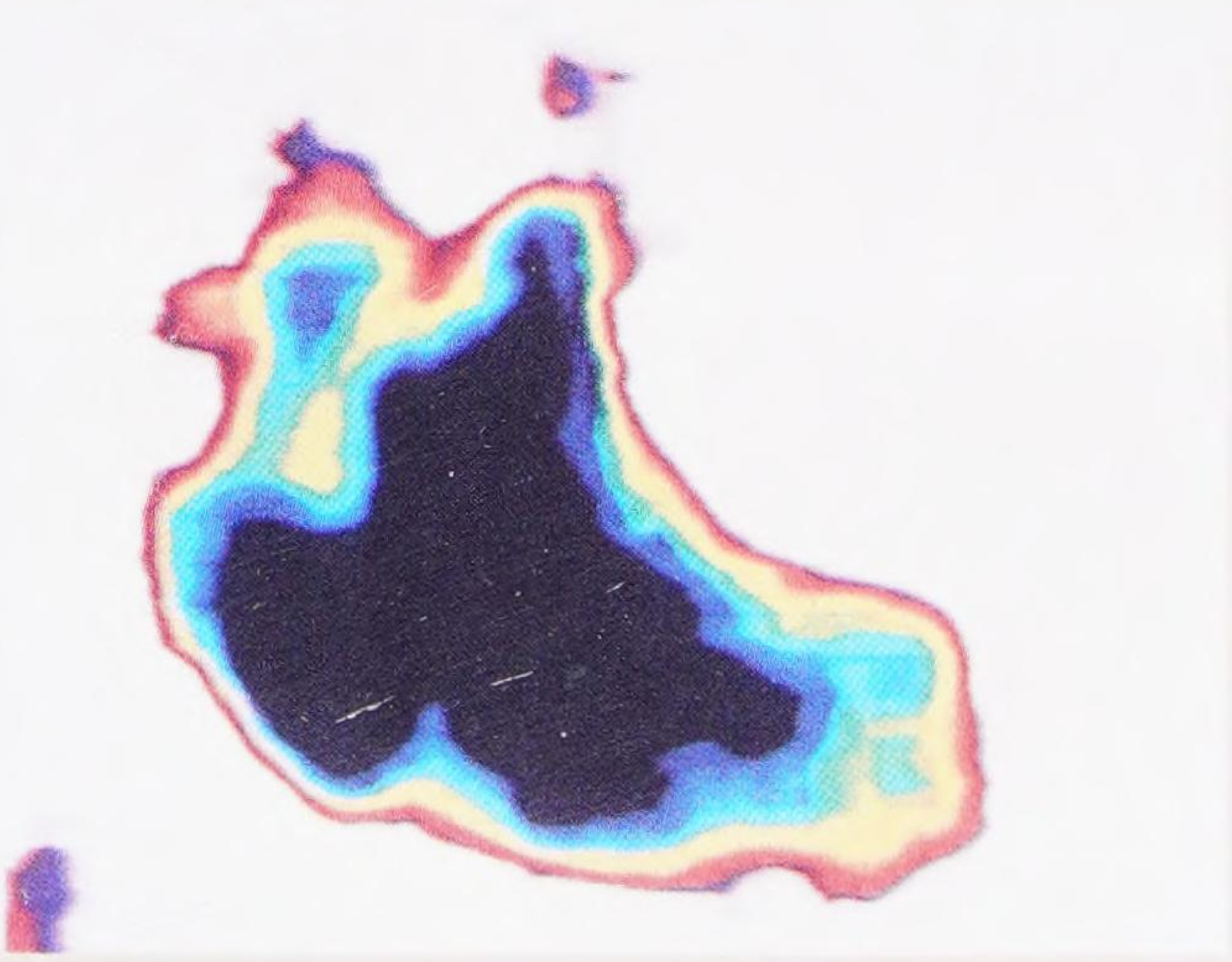
Super Sleuth!

Doctors have several tools for diagnosing diseases. One of the newest tools is magnetic resonance imaging (MRI).

Here's how it works. A person with a condition that needs to be diagnosed is placed in an MRI machine. The machine generates a powerful magnetic field in the body. In the body, the nuclei inside the atoms line up parallel to the magnetic field. Then, the nuclei are jolted with very fast radio waves. The nuclei resonate, or vibrate, like tiny tuning forks, producing a faint radio signal. This signal creates a picture of the body in great detail.

Using MRI, scientists have discovered changes in the brain that may be used to diagnose Alzheimer's disease. Doctors hope that MRI can be used to evaluate medicines for heart problems and cancer.

Think Critically: What advantages does MRI have over other methods that are used to diagnose disease?



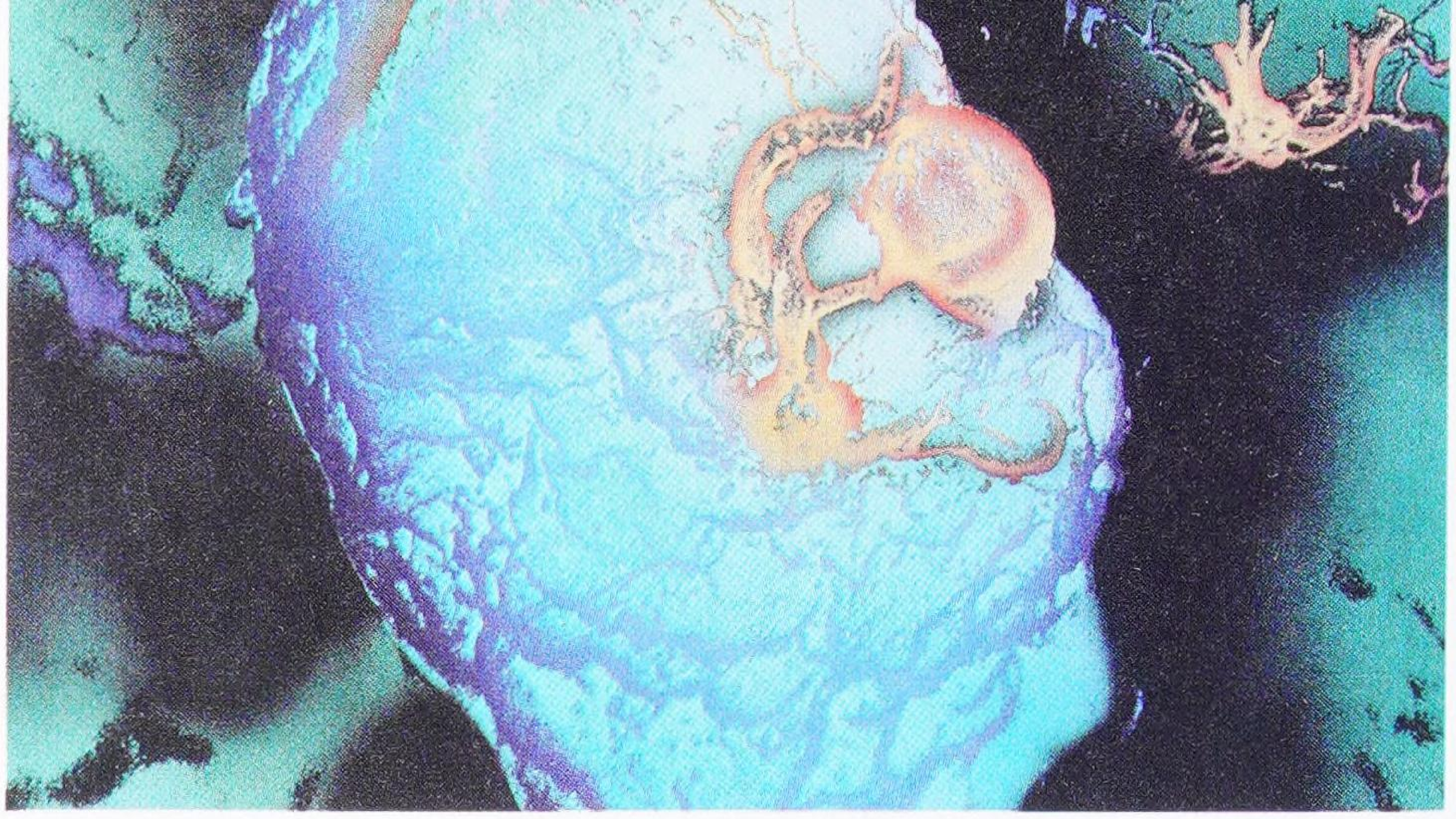


Figure 24-7. Infection by HIV can result in AIDS. HIV destroys lymphocytes, cells in the body that are vital to fighting disease.

Connect to... Chemistry

In laboratory tests, a chemical from a tree in the rain forest of a Samoan island has been found to shield cells from HIV. How does this discovery stress the need to prevent the destruction of rain forests?

HIV and Your Immune System

HIV is different from other viruses. It attacks cells in the immune system called lymphocytes. **Lymphocytes** are white blood cells throughout the lymphatic system that chemically recognize antigens. They then produce antibodies and destroy invading antigens.

Because HIV destroys lymphocytes, the body is left with no way to fight invading antigens. The whole immune system breaks down. The body is unable to fight HIV, or any other pathogen. For this reason, people with AIDS die from other diseases such as pneumonia, cancer, or tuberculosis. The victim's body becomes defenseless.

When a microbe attacks your body, it must get past all of your natural defenses. If it gets past your skin or other defenses, it encounters your immune system—your last line of defense. But if HIV has destroyed the immune system, there is no defense left.

SECTION REVIEW

1. List natural defenses your body has against disease.
2. Why does passive immunity need to be renewed throughout life?
3. What cells does HIV attack?
4. **Apply:** Why might someone have to receive booster injections of antibodies?
5. **Connect to Chemistry**: Find out how genetic engineers are creating plants and animals that are pest resistant.

Skill Builder

Comparing and Contrasting

Compare and contrast active and passive immunity. If you need help, refer to Comparing and Contrasting in the **Skill Handbook** on page 683.

ACTIVITY 24-1

Microorganisms and Disease

Problem: *How do microorganisms cause infection?*

Materials

- fresh apples (6)
- rotting apple
- alcohol
- self-sealing plastic bags (6)
- labels and pencil
- paper towels
- sandpaper
- cotton ball
- soap and water

Procedure

1. Label the plastic bags 1 through 6.
2. Put a fresh apple in bag 1 and seal the bag.
3. Rub the rotting apple over the entire surface of the remaining 5 apples. The rotting apple is your source of microorganisms. **CAUTION:** *Always wash your hands after handling microorganisms.* Take one of the apples and put it in bag number 2.
4. Drop one apple to the floor from a height of about two meters. Put this apple into bag number 3.
5. Rub one of the remaining apples with sandpaper. Place this apple in bag number 4.
6. Wash one of the last two apples with soap and water. Dry the apple well with a paper towel. Put this apple in bag number 5.
7. Use a cotton ball to spread alcohol over the last apple. Let the apple air-dry for a short time. Watch it and as soon as it is dry place the apple in bag number 6.
8. Place all of the apples in a dark place for one week.Then wash your hands.
9. Write a **hypothesis** to explain what you think will happen to each apple.
10. At the end of the week, compare all the apples. Record your observations. **CAUTION:** *Give all apples to your teacher for proper disposal.*

Data and Observations

Apple	Observations
1	
2	
3	
4	
5	
6	

Analyze

1. What was the purpose of apple number 1?
2. Did you *observe* any changes in apple number 2? Explain.
3. What happened on apples 3 and 4?
4. What effect did the soap and water have?

Conclude and Apply

5. Did you *observe* changes in apple number 6?
6. Why is it important to wash your hands before eating?
7. Why is it important to clean a wound?
8. Were your **hypotheses** supported?
9. *Relate* microorganisms and infection.

Isopropyl Rubbing Alcohol
1
4

SCIENCE & SOCIETY

24-3 Preventing Disease

New Science Words

vaccination

Objectives

- Explain how vaccination prevents certain diseases.
- Explain how disease can be prevented from spreading.

Guarding Against Disease

Vaccination is the process of giving a vaccine by injection or by mouth. In Chapter 8, you learned that the first vaccine was invented by an English doctor, Edward Jenner. An epidemic of smallpox was killing many people in Europe. In 1980, the World Health Organization promoted a successful vaccination program to eliminate smallpox from the world.

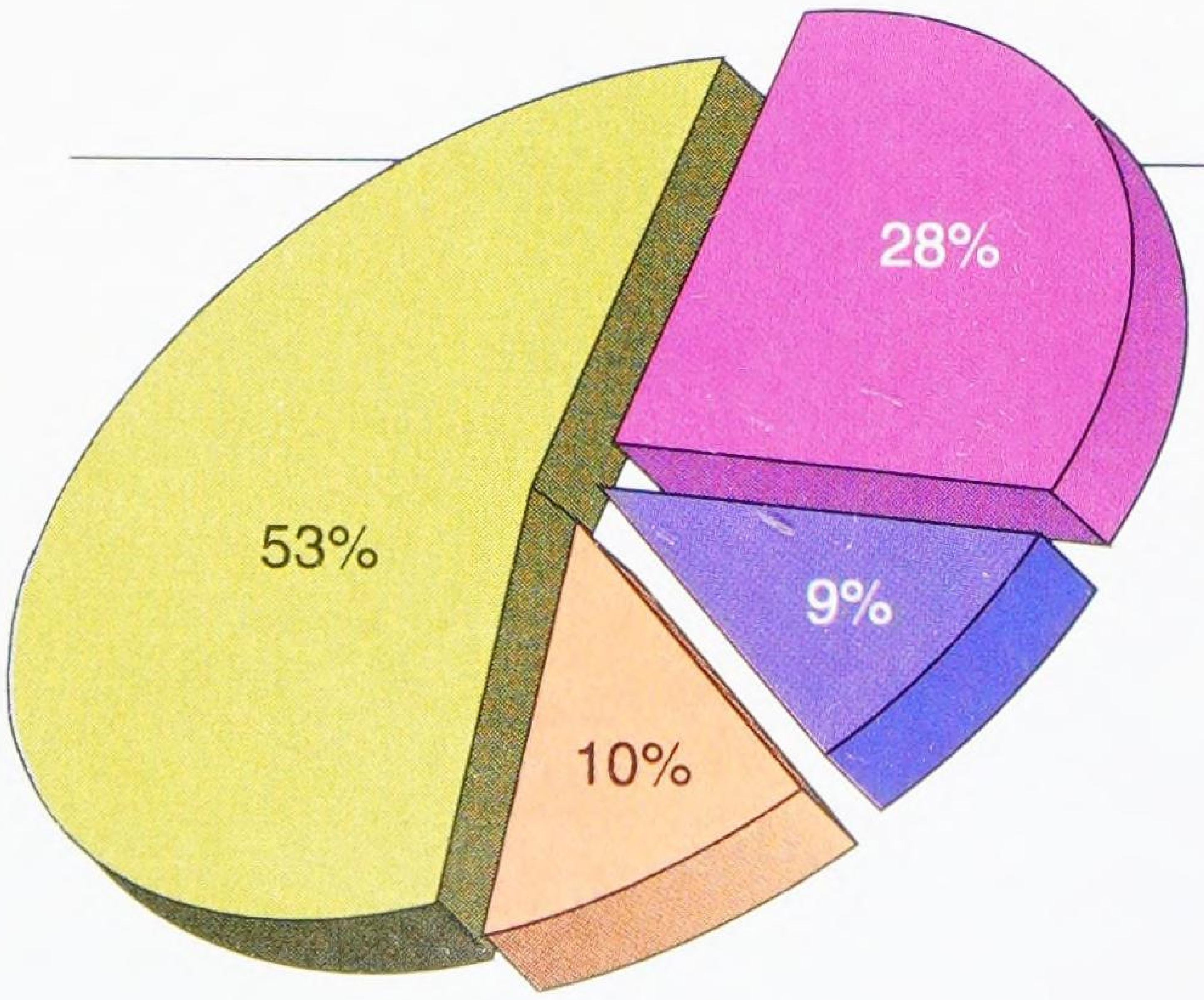
In the 1950s, polio vaccines were developed by Jonas Salk and Albert Sabin. Because children are vaccinated against polio, your chances of getting this disease are near zero. Other diseases that you can be vaccinated against include measles, mumps, and diphtheria. Early in life, most of you received vaccines to protect you from these diseases.

Some of these diseases have begun to reappear. In the United States, more cases of measles were reported in 1989 than in 1988. College campuses are reporting cases of mumps in young adults. About 20 000 new cases of tuberculosis (TB) are reported each year.

Connect to... Chemistry

Inactivated substances from infectious organisms that are used for vaccinations are called toxoids. Find out what toxoids are in DPT vaccine.

CASES OF TUBERCULOSIS IN LARGE CITIES OF THE UNITED STATES



	Population of City	Number of cases
🟪	500 000	6396
🟦	250 000 to 500 000	2081
🟧	100 000 to 250 000	2130
🟨	All other areas	11 910
	Total	22 517

According to the Centers for Disease Control, there are two reasons for the return of these diseases. First, many babies are not being vaccinated against mumps, measles, tetanus, whooping cough, and polio. While some children have shown reactions to the whooping cough vaccine, most children receive vaccines for these diseases by the age of 15 months. Second, just one dose of vaccine does not always provide enough protection. Many adults forget that they need booster shots for tetanus and possibly measles.

Tuberculosis is returning due in part to the damaged immune systems of AIDS victims. Unable to fight off the tuberculosis bacterium, AIDS patients often develop that disease. Those who work or live with such individuals are then exposed to tuberculosis and have a greater chance of developing the disease.

What can you do to prevent becoming infected with these diseases? Make sure you have been vaccinated. Check your medical records to be sure you are vaccinated against all of these diseases. Also, doctors recommend a second vaccination for measles, especially among college students, to rebuild their immunity to the virus. Keeping clean, eating a balanced diet, getting rest and exercise, and getting medical care when you need it are ways to maintain health.

Table 24-3

VACCINATION SCHEDULE

Vaccine	Age
Oral polio	2 months 4 months 18 months 5-6 years
Diphtheria pertussis, tetanus (DPT)	2 months 4 months 6 months 18 months 5-6 years
Tetanus-diphtheria (Td)	14-16 years, every 10 years
Measles, Mumps, Rubella (MMR)	15 months
Measles	17 years
Tuberculosis (TB)	Test in U.S. Some countries give a vaccine

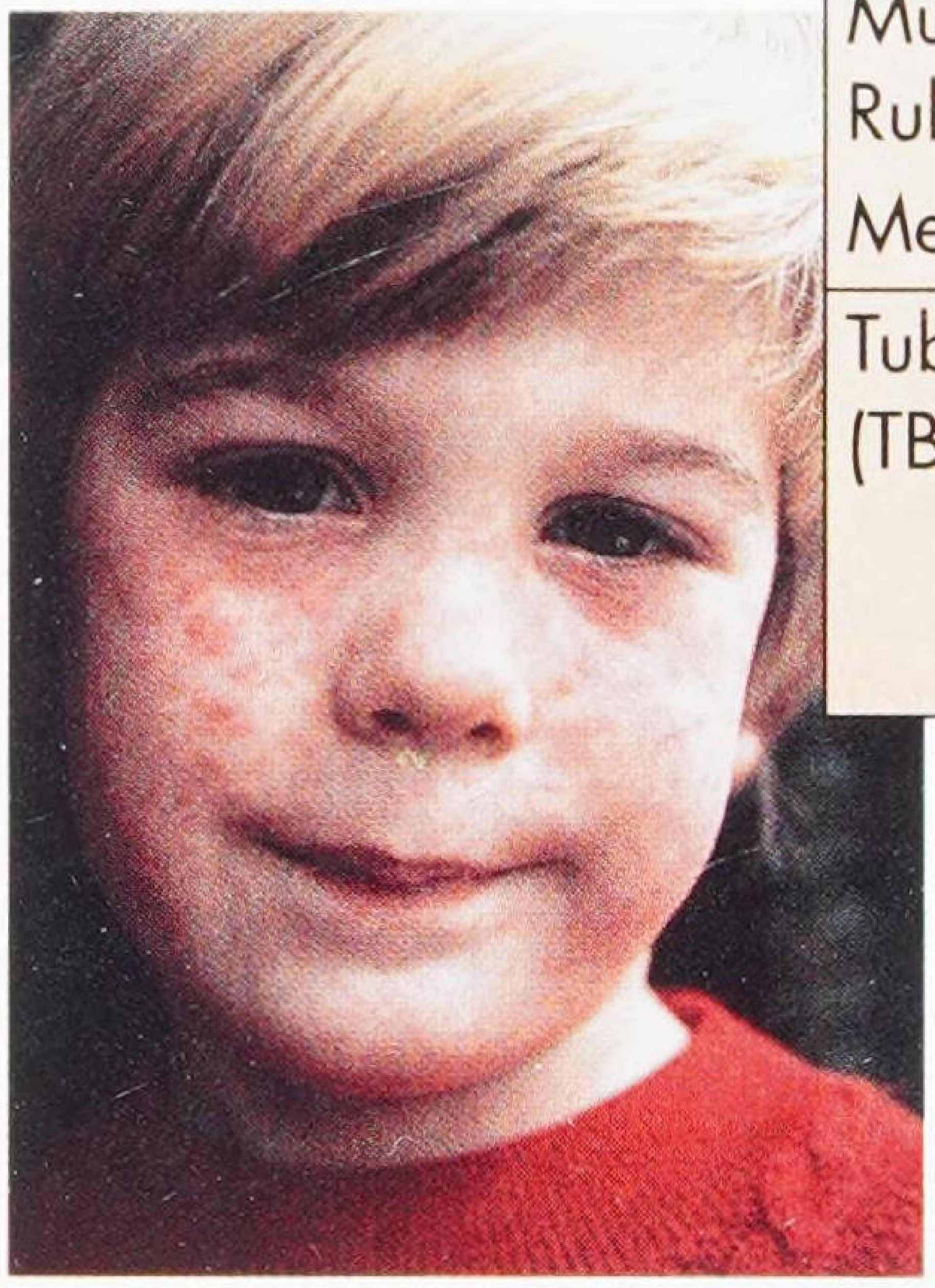


Figure 24-8. This child shows symptoms of the measles virus.

SECTION REVIEW

1. How does vaccination help prevent disease?
2. Why is vaccination important for the population of a country?
3. **Connect to Chemistry:** Find out about the use of gamma globulin as an innoculation for certain diseases.

You Decide!

SCIENCE & SOCIETY

The last case of smallpox was in 1980 in Somalia in Africa. Now the only places where the smallpox virus exists is in the Centers for Disease Control in Atlanta, GA, and in a similar facility in the Soviet Union. Should these countries destroy the remaining virus samples? Should they keep them? Can you think of any benefit for keeping the virus samples?

24-4 Noncommunicable Disease

New Science Words

noncommunicable diseases
chronic diseases
cancer
tumor
chemotherapy
allergy
allergens

Objectives

- List two noncommunicable diseases.
- Describe the basic characteristics of cancer.
- Name two chronic diseases of the immune system.

Chronic Disease

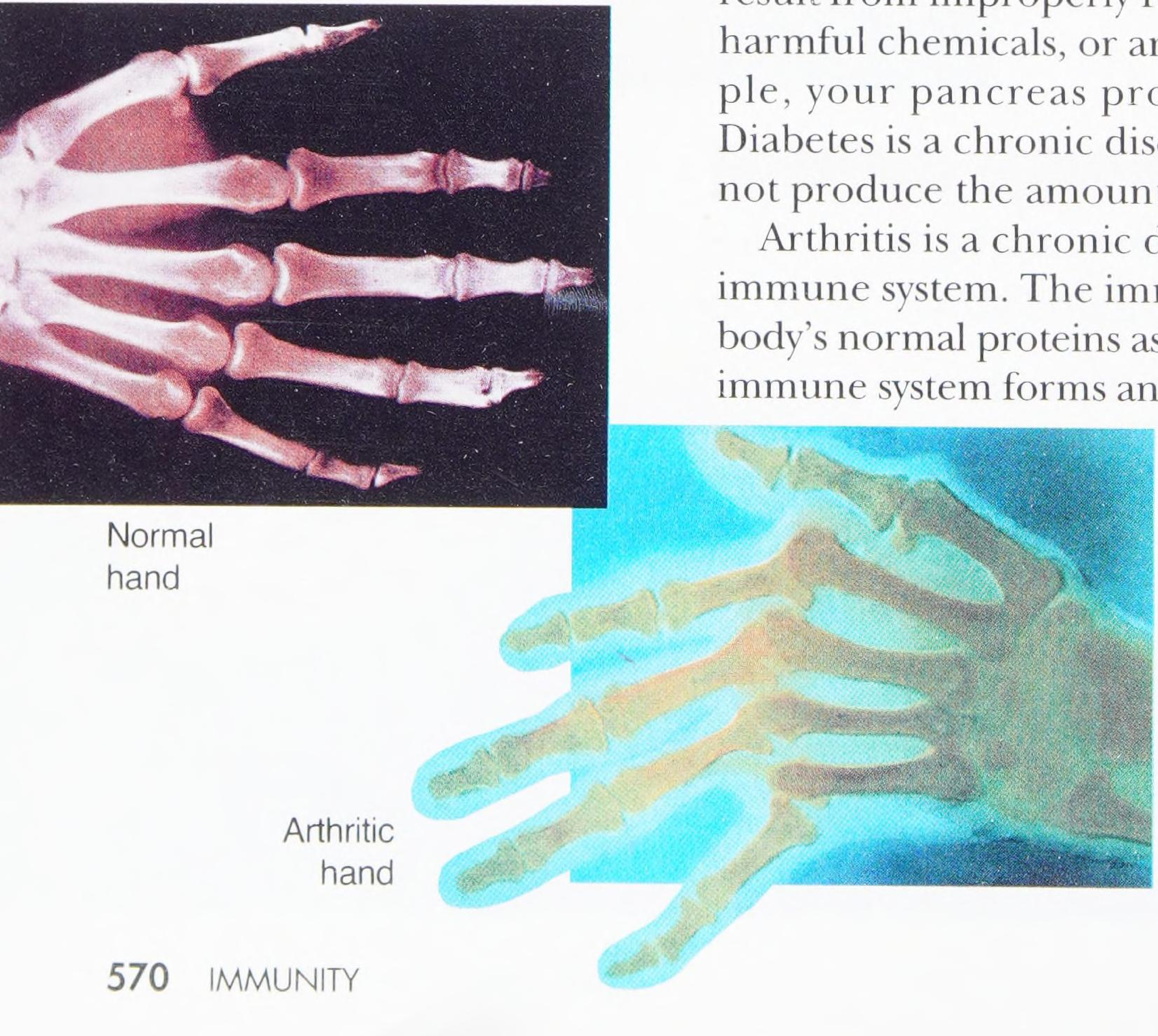
Diseases and disorders such as diabetes, allergies, asthma, cancer, and heart disease are not caused by pathogens. These diseases are called **noncommunicable diseases** because they are not spread from one person to another. You can't "catch" them. Allergies, genetic disorders, life-style diseases, or chemical imbalances such as diabetes, are not spread by sneezes or handshakes.

Some noncommunicable diseases are called **chronic diseases** because they last a long time. Some chronic diseases can be cured. Others cannot. Chronic diseases may result from improperly functioning organs, contact with harmful chemicals, or an unhealthy life-style. For example, your pancreas produces the hormone insulin. Diabetes is a chronic disease in which the pancreas cannot produce the amount of insulin the body needs.

Arthritis is a chronic disease that results from a faulty immune system. The immune system begins to treat the body's normal proteins as if they were antigens. The faulty immune system forms antibodies against the normal proteins in joints. Movement becomes difficult and painful.

Some chronic diseases are caused by chemicals. Household cleaners, car exhaust, and cigarette smoke are examples. Cigarette smoke has been linked with lung cancer, other lung diseases, and heart disease.

Figure 24-9. Arthritis turns the body's immune system against itself. Joints may be severely deformed.



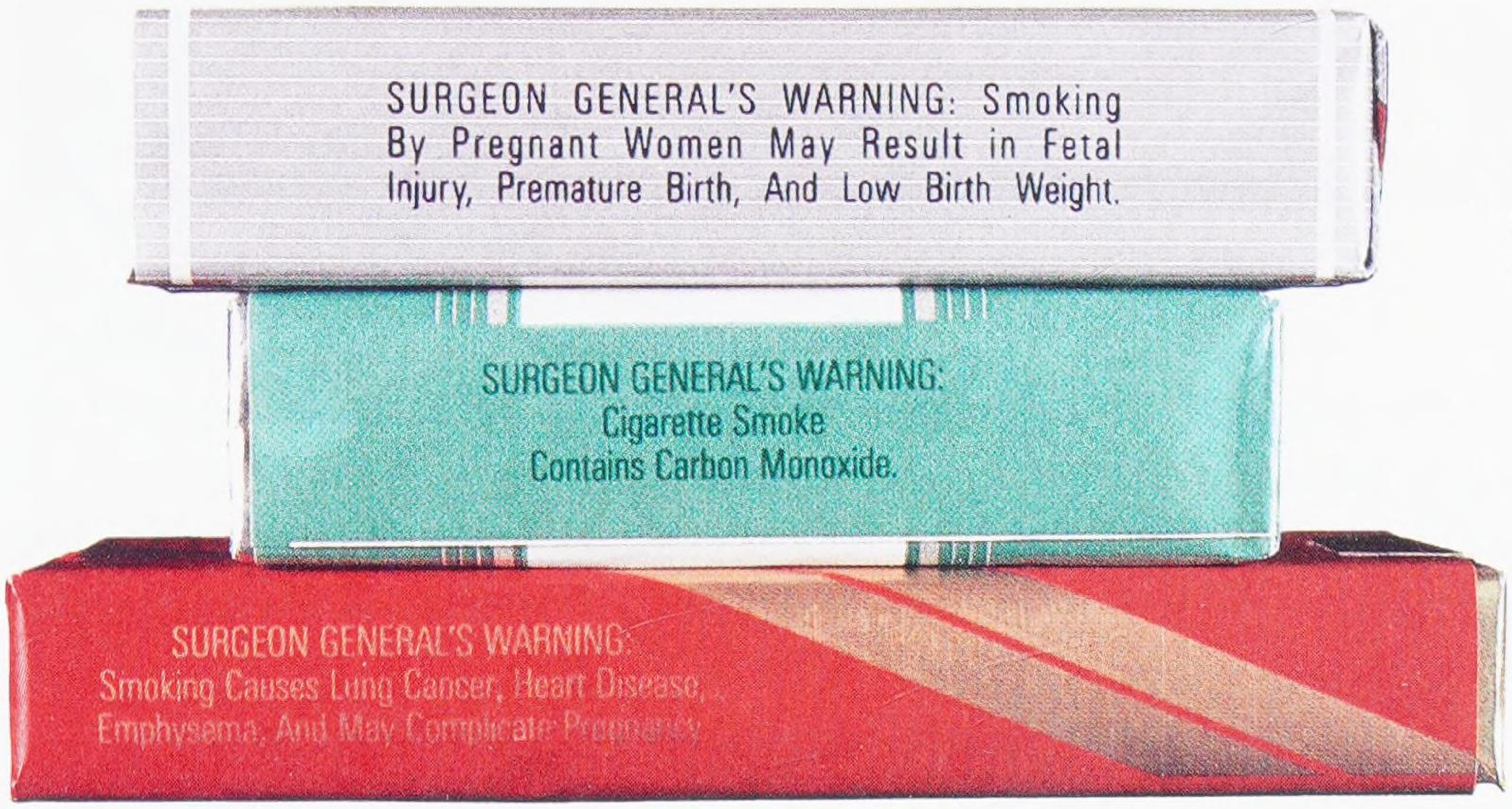

SURGEON GENERAL'S WARNING: Smoking By Pregnant Women May Result in Fetal Injury, Premature Birth, And Low Birth Weight.
SURGEON GENERAL'S WARNING: Cigarette Smoke Contains Carbon Monoxide.
SURGEON GENERAL'S WARNING: Smoking Causes Lung Cancer, Heart Disease, Emphysema, And May Complicate Pregnancy.

Figure 24-10. Tobacco products have been directly linked to lung cancer.

Cancer

Cancer is a major chronic disease. **Cancer** results from uncontrolled cell growth. There are many different types of cancer, but most of them have these characteristics:

1. Uncontrolled cell growth results in large numbers of cells.
2. The large number of cells do not function as a part of the body.
3. The cells take up space and interfere with normal bodily functions.
4. The cells do not remain in one place, but travel throughout the body. In this way, cancer spreads and grows in many areas of the body.

A **tumor** is an abnormal growth anywhere in the body. If a tumor is near the surface of the body, you may feel it as a lump. But if it is deep inside the body, it may go undetected for years. There are two kinds of tumors, benign and malignant (muh LIHG nuhnt). Benign tumors are not cancerous. Malignant tumors are cancerous and can spread.

Treatment for cancer includes surgery to remove cancer tissue, radiation with X rays to kill cancer cells, and chemotherapy. **Chemotherapy** is the use of chemicals to destroy cancer cells.

Cancers are complicated, and no one fully understands how they form. Some scientists hypothesize that cancer cells form regularly in the body. However, the immune system destroys them. Only if the immune system fails or becomes overwhelmed, does the cancer begin to expand. Smoking, poor diet, and exposure to harmful chemicals encourage some cancers to form.

Science and MATH

Aside from the health reasons for not smoking, look at an economic one. **In your Journal,** *calculate* the amount of money a person will save in a week and in a year by not smoking. Assume that the person smokes a pack a day and the cost is $1.50 per pack.

Table 24-4

CAUSES OF CANCER	
Carcinogens Substances that cause cancer:	
smoking	air pollution
asbestos dust	high fat diet
ultraviolet light	aflatoxins
radiation	
Oncogenes Genes that cause a normal cell to become cancerous	

Allergies

Have you ever broken out in an itchy rash after eating a favorite food? An **allergy** is an overly strong reaction of the immune system to a foreign substance. Many people have allergic reactions to cosmetics, shrimp, strawberries, and bee stings. Allergic reactions to some things such as antibiotics can even be fatal.

Substances that cause the allergic response are called **allergens.** These are substances that the body would normally respond to as a mild antigen. Chemicals, dust, grass, food, pollen, molds, and some antibiotics are allergens for some sensitive people. When you come in contact with an allergen, your immune system forms antibodies, and your body may react in many ways. When the body responds to an allergen, chemicals called histamines are released. Histamines promote red, swollen tissues. Allergic reactions are sometimes treated with antihistamines. Pollen is an allergen that causes a stuffy nose, breathing difficulties, watery eyes, and a tired feeling in some people. Some foods cause blotchy rashes such as hives or, stomach cramps and diarrhea. Most allergic reactions are minor. But severe allergic reactions can occur, causing shock and even death if not treated promptly. Some severe allergies are treated with repeated injections of small doses of the allergen, which allows the body to become less sensitive to the allergen.

Noncommunicable diseases aren't spread from person to person. So, you don't have to worry about catching

Connect to... Chemistry

Antihistamines are chemicals that are used to counteract the histamines released in response to allergens. What side effects may be associated with antihistamines?

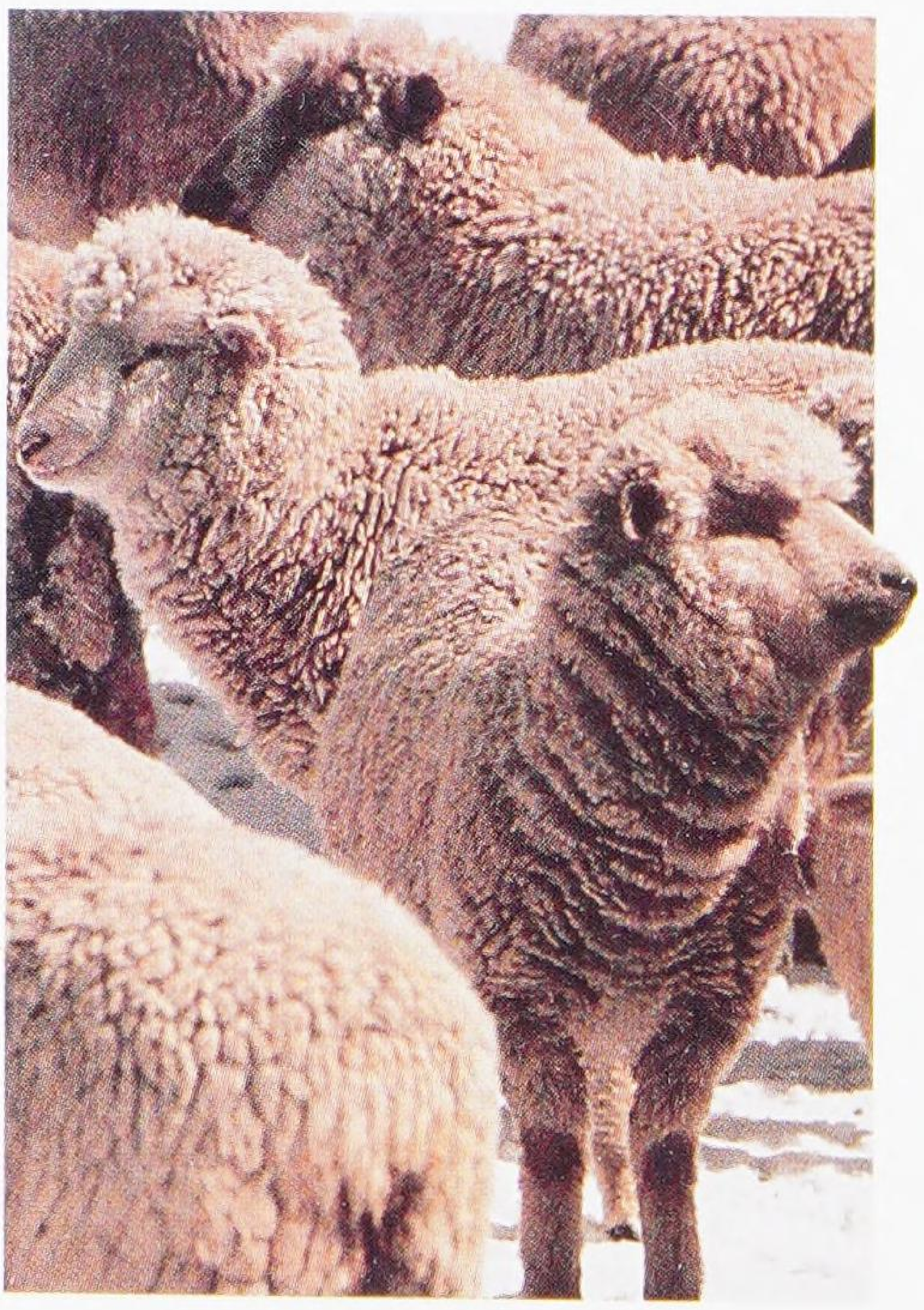


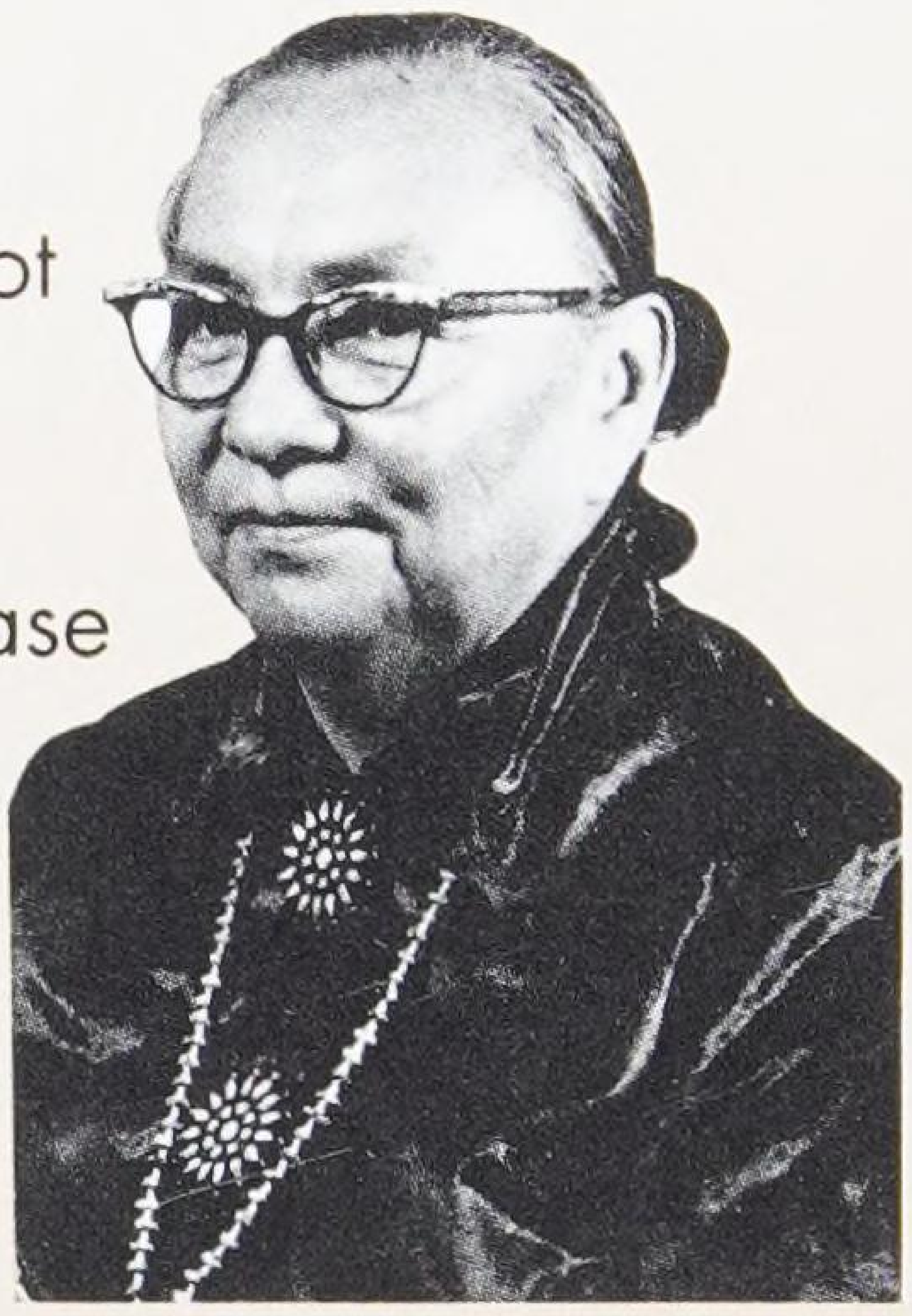
Figure 24-11. Some common substances such as cosmetics, foods, and wool from sheep stimulate allergic responses in people.

PROBLEM SOLVING

Fighting TB

Annie Dodge Wauneka, the daughter of a Navajo chief, has spent much of her life fighting tuberculosis (TB). She was the first woman elected to the Tribal Council, and was appointed chairperson of the health committee. TB killed many people on the reservation each year, so Wauneka decided to learn everything she could to fight it. She wrote a Navajo-English medical dictionary and got Navajo and non-Navajo doctors to work together on the disease. She also encouraged Navajo patients to trust non-Navajo doctors and to get early diagnosis. Her war against TB was so successful that she was awarded the Freedom Award, and the Navajo gave her the name "Warrior Who Scouts the Enemy."

Think Critically: Annie Dodge Wauneka was not a doctor. How was she able to help fight a disease without medical knowledge?



diabetes, cancer, or allergies from someone else. But, left untreated, noncommunicable diseases can be as deadly as AIDS or untreated syphilis. After all, most people die from chronic heart disease and cancer, and not from a virus or bacterium.

SECTION REVIEW

1. What are two noncommunicable diseases?
2. What are the basic characteristics of cancer?
3. What are two chronic diseases of the immune system?
4. **Apply:** Joel has an ear infection. The doctor prescribes an antibiotic. After taking the antibiotic, Joel breaks out in a rash and has difficulty breathing. What is happening to him? What should he do immediately?
5. **Connect to Chemistry:** Find out about diseases associated with a diet that is deficient in iron.

Making and Using Tables

Skill Builder

Make a table that lists some chronic diseases and their treatments. Use the information you have read in this section. If you need help, refer to Making and Using Tables in the **Skill Handbook** on page 690.

DESIGNING AN EXPERIMENT

ACTIVITY 24–2

Preventing Microorganism Growth

From this chapter, you know that without cleanliness there is a good chance of getting an infection when you scrape an arm or knee. Infections are caused by microorganisms. Preventing the growth of microorganisms is one way to control infections and the spread of disease. Disinfectants are chemicals that kill or remove disease organisms from objects. Antiseptics are chemicals that kill or prevent the growth of disease organisms on living tissue. In this activity, you will be the scientist and find out how to prevent the growth of microorganisms.

Getting Started

In preparation for designing your experiment, answer the following questions:

1. What question are you investigating?
2. What do microorganisms need to grow?
3. What variables are important in this experiment?

Safety Notes

Use only common household disinfectants and antiseptics—no dangerous chemicals. Seal all plates being tested with tape. At the end give your plates to your teacher for proper disposal.

Hypothesis

What is your **hypothesis?** What is the reasoning behind your hypothesis? Choose the best idea to investigate and decide on a hypothesis.

Brainstorm

Working in groups of 3 or 4, decide how to prevent the growth of microorganisms using culture dishes. How can you test your hypothesis?

Experiment Plan

- **Design your experiment** to test one variable. Make sure you plan to collect quantitative data.
- In a numbered list, similar to a recipe, make a set of directions that anyone can follow to do the experiment.
- Make a list of materials and the quantities needed to do the experiment. (Ask your teacher for sterile nutrient agar plates.)

Answer the Following Questions

1. Do you need a control? If so, what will the control be?
2. What will you measure?
3. Have you limited the number of substances you will test?
4. Develop a data table for collecting quantitative data.

Make sure your teacher has approved your experimental plan before you go further.

Data and Observations

Carry out your experiment and make a data table of your observations.

Data Analysis and Interpretation

1. What substances appeared to be most effective in controlling microorganisms?
2. What substances appeared to be least effective?
3. What happened to the control?
4. How do disinfectants and antiseptics affect microorganism growth?

Going Further

Design an experiment to determine if sunlight has an effect on microorganism growth.

CHAPTER REVIEW

SUMMARY

24-1: The Nature of Disease

1. Pasteur and Koch discovered that diseases are caused by microbes. Lister used disinfectants to help control microbes.

2. Communicable diseases caused by pathogenic bacteria, viruses, fungi, and protists can be passed from one person to another by air, water, food, and animal contact.

3. Sexually transmitted diseases (STDs) are passed between persons during sexual contact. They include genital herpes, gonorrhea, chlamydia, and syphilis. AIDS is classified as a communicable disease and as an STD.

24-2: Your Immune System

1. The body is protected against pathogens by skin, cilia and mucus in the respiratory system, white blood cells in the circulatory system, and digestive enzymes. The purpose of the immune system is to fight disease.

2. Active immunity is long-lasting; passive immunity does not last.

3. AIDS is a communicable disease that may be transmitted by sexual contact, by using a needle contaminated by someone who already has the disease, by transfusion with contaminated blood, and through the placenta to a developing fetus. AIDS damages the body's immune system so that it cannot fight any disease.

24-3: Science and Society: Preventing Disease

1. A vaccine is a weakened virus delivered by injection or swallowed to develop immune protection against a disease.

2. Disease can be prevented by vaccination and good health habits.

24-4: Noncommunicable Disease

1. Causes of noncommunicable disease include genetics, chemicals, poor diet, and uncontrolled cell growth.

2. Chronic noncommunicable diseases include diabetes, cancer, arthritis, and allergies.

3. Most noncommunicable diseases can be medically treated.

KEY SCIENCE WORDS

a. **active immunity**
b. **allergens**
c. **allergy**
d. **antibody**
e. **antigens**
f. **antiseptic**
g. **cancer**
h. **chemotherapy**
i. **chronic diseases**
j. **communicable disease**
k. **disinfectant**
l. **immune system**
m. **lymphocytes**
n. **noncommunicable diseases**
o. **passive immunity**
p. **pasteurization**
q. **sexually transmitted diseases (STDs)**
r. **tumor**
s. **vaccination**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. cause allergic reactions
2. disease spread through air, water, or contact
3. chemical that prevents pathogen growth on the skin
4. foreign proteins attacked by the body
5. introduces antibodies for short-term immunity
6. white blood cells that fight pathogen
7. long-lasting, noncommunicable diseases
8. uncontrolled cell division
9. use of chemicals to destroy cancer cells
10. introduces antigens for long-term immunity

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. A pathogen causes a specific disease if it is _______.

a. present in all cases of the disease
b. does not infect other animals
c. causes other diseases
d. treated with heat

2. Communicable diseases can be caused by _______.

a. heredity **c.** chemicals
b. allergies **d.** organisms

3. _______ is an example of an STD.

a. Anthrax **c.** AIDS
b. Malaria **d.** Pneumonia

4. All of these diseases are caused by bacteria except _______.

a. AIDS **c.** chlamydia
b. gonorrhea **d.** syphilis

5. Your body's defenses against pathogens include all of the following except _______.

a. stomach enzymes **c.** white blood cells
b. skin **d.** hormones

6. All of these are noncommunicable diseases except _______.

a. allergies **c.** asthma
b. syphilis **d.** diabetes

7. Lymphocytes are attacked by the virus that causes _______.

a. AIDS **c.** flu
b. chlamydia **d.** polio

8. _______ is a chronic joint disease.

a. Asthma **c.** Muscular dystrophy
b. Arthritis **d.** Diabetes

9. Cancer cells are destroyed by _______.

a. chemotherapy **c.** vaccines
b. antigens **d.** viruses

10. _____ are formed by the blood to fight invading antigens.

a. Hormones **c.** Pathogens
b. Allergens **d.** Antibodies

USING LAB SKILLS

11. In the MINI-Lab on page 560 a method to detect bacteria in foods is described. Use this method to compare the amount of bacteria in raw versus cooked hamburger. What did you discover?

12. The Activity on page 567 asked you to find out how microorganisms cause infections. Try using hydrogen peroxide (3%) to clean an infected apple. Determine if it stops bacterial growth.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. How did Pasteur's experiments help society?

14. What makes arthritis different from other immune disorders?

15. Why is it very important to wash your hands after using a restroom, petting a dog, handling a pet gerbil or parakeet, and before eating?

16. If a person gets a bacterial STD, why must it be treated promptly with antibiotics?

17. What's the difference between active and passive immunity?

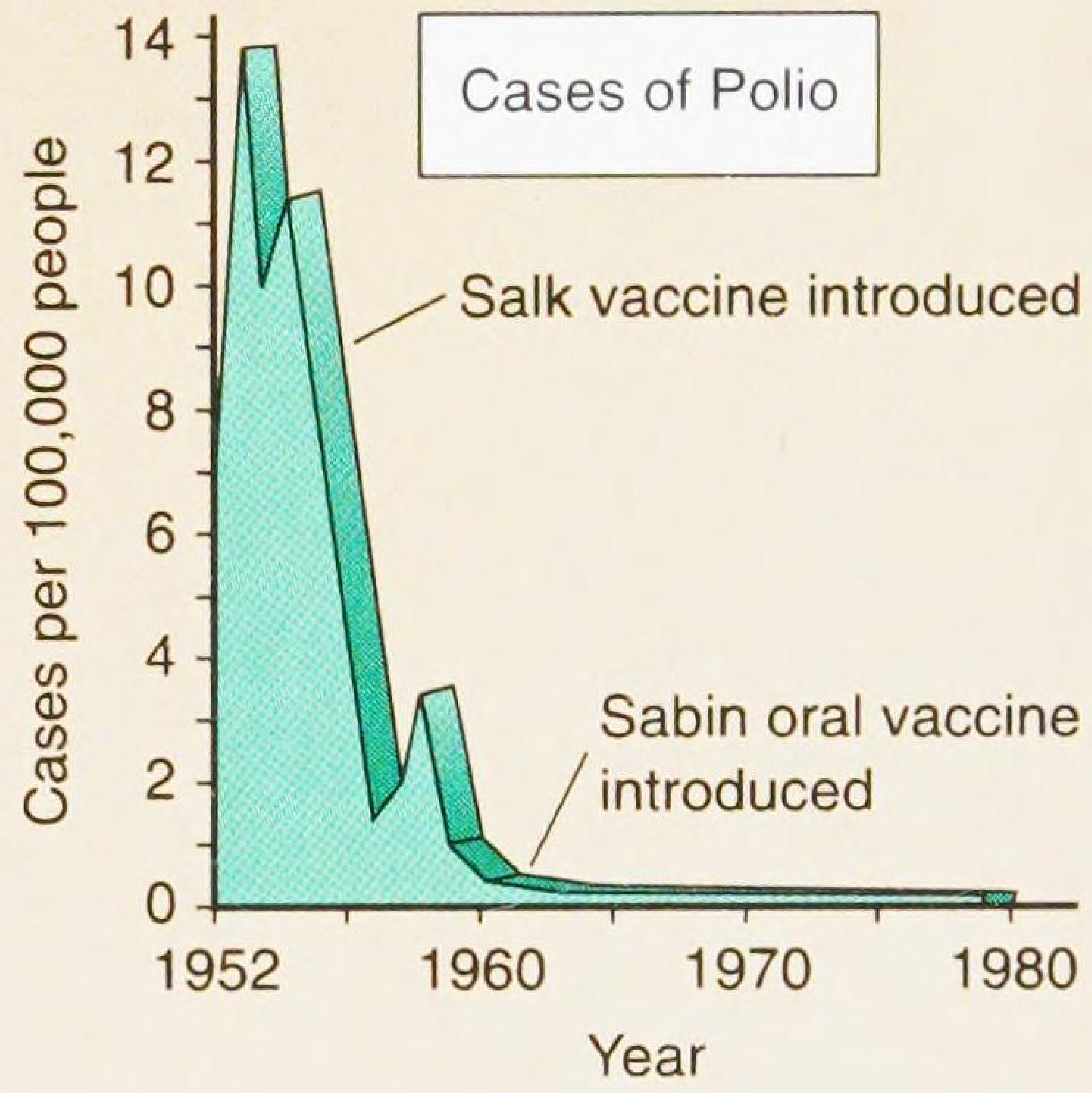
APPLY

18. Which is better—to vaccinate people or to wait until they build their own immunity?
19. What advantage might a breast-fed baby have compared to a bottle-fed baby?
20. How does your body protect itself from antigens?
21. How do lymphocytes eliminate antigens?
22. Describe the differences among antibodies, antigens, and antibiotics.

MORE SKILL BUILDERS

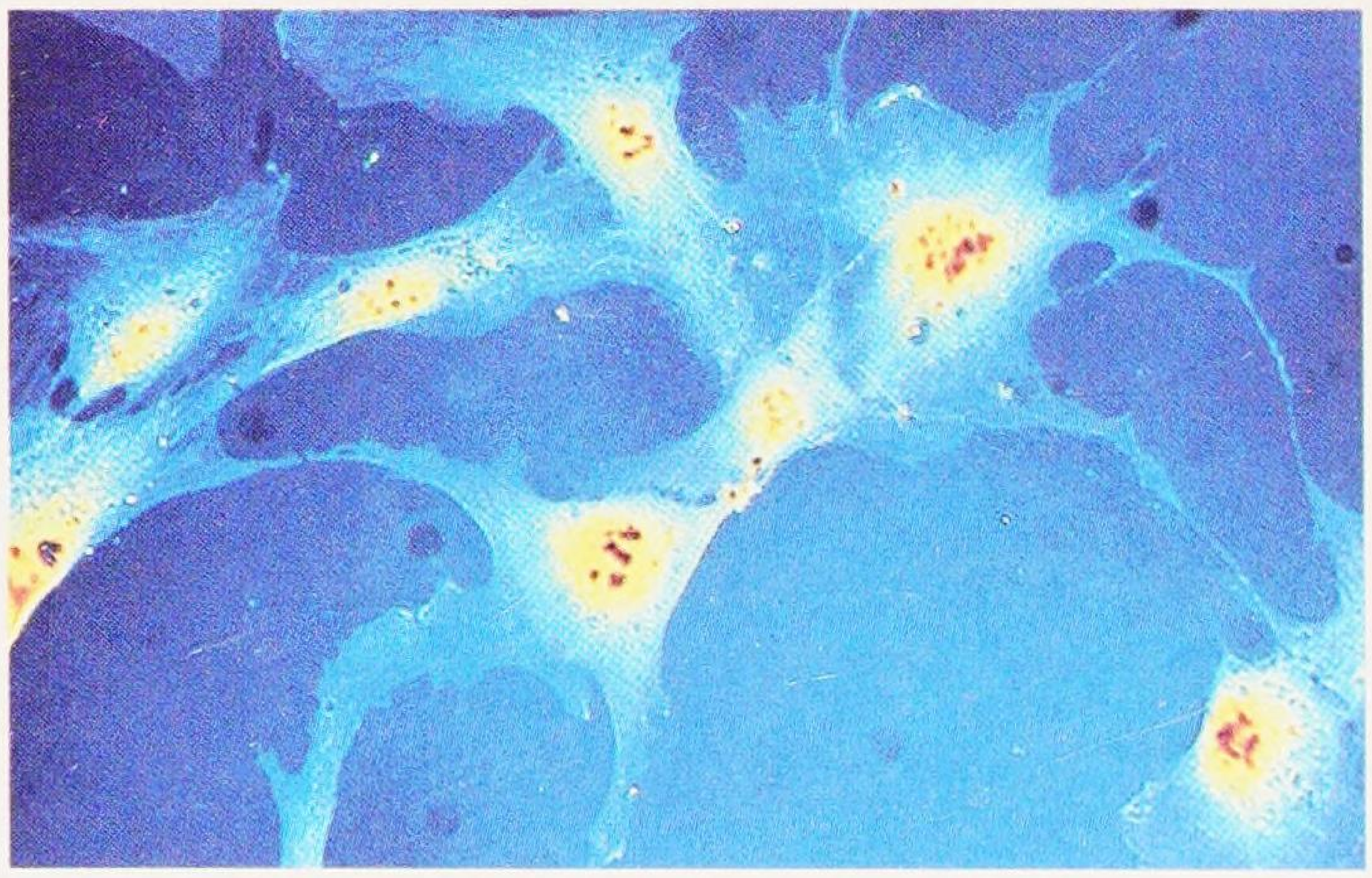
If you need help, refer to the Skill Handbook.

1. **Making and Using Tables:** Make a chart comparing the following diseases and their prevention: cancer, diabetes, tetanus, measles.
2. **Concept Mapping:** Make network tree concept map, comparing the defenses your body has against disease. Compare general defenses, active immunity, and passive immunity.
3. **Classifying:** Classify the following diseases as communicable or noncommunicable: diabetes, gonorrhea, herpes, strep throat, syphilis, cancer, flu.
4. **Recognizing Cause and Effect:** Use a library reference to identify the cause of each disease as bacteria, virus, fungus, or protist: athlete's foot, AIDS, cold, dysentery, flu, pinkeye, pneumonia, strep throat, ringworm.
5. **Making and Using Graphs:** Interpret the graph below showing the rate of polio cases. Explain the rate of cases between 1950 and 1965. What conclusions can you draw about the effectiveness of the polio vaccines?



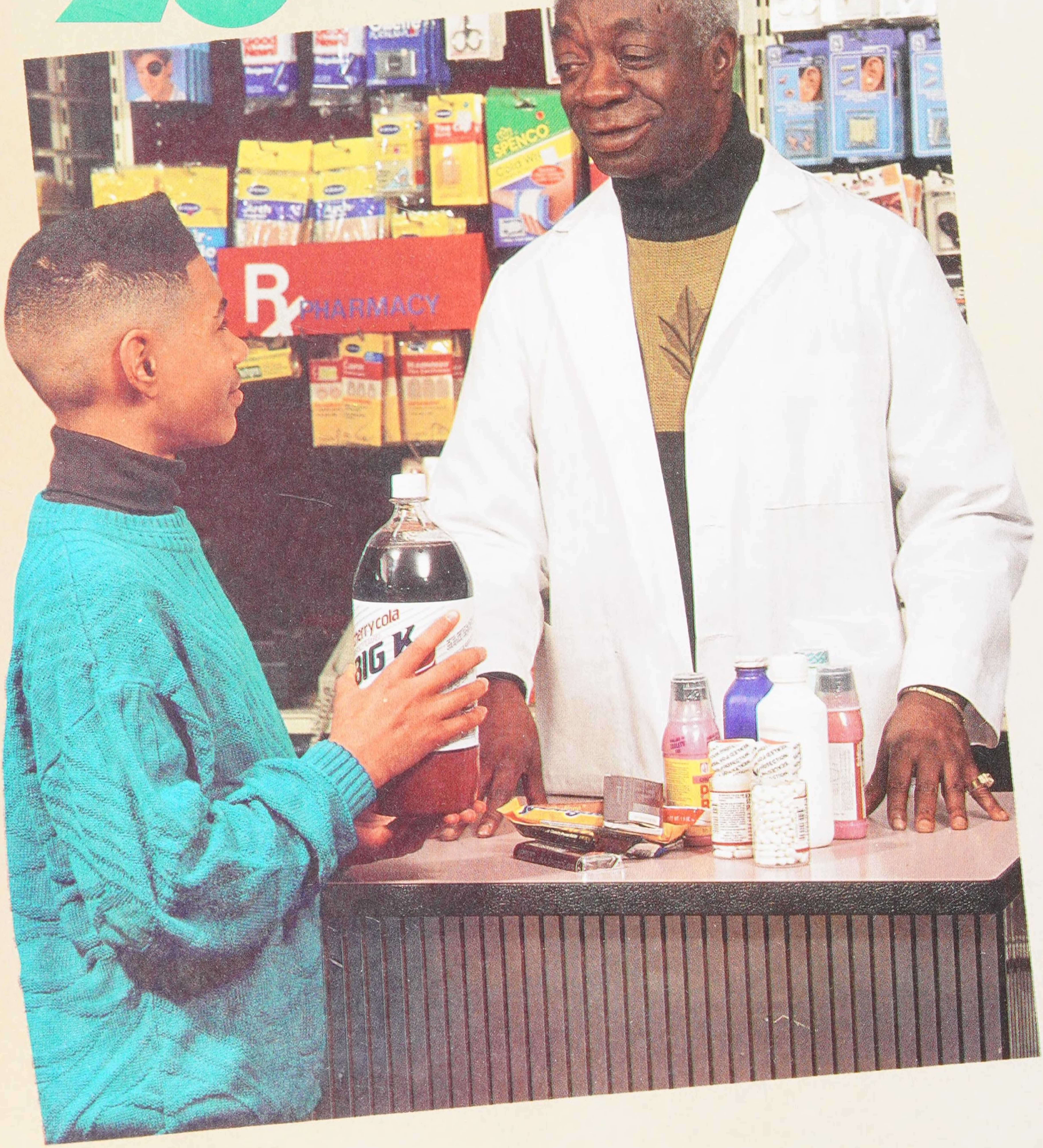
PROJECTS

1. Design a flow chart (diagram) to show how a person with a cold could spread the disease to family members and to others.
2. Write a report on Lyme disease, its causes, symptoms, and treatment.



CHAPTER

25 Facts about Drugs


PHARMACY
BIG K

Drugs are chemical substances that are used to help lessen pain, to cure disease, or control a chemical imbalance in the body. Drugs have important roles in overcoming illness and maintaining a healthy life.

FIND OUT!

Do this activity to find out which foods and drinks contain caffeine.

Read the labels of food and medicine products to see if the stimulant drug caffeine is listed as an ingredient. Design a chart to show the amount of caffeine per serving or dose in ten of these items. *Compare* and rank the products from those containing the most caffeine to those containing the least. What products surprised you because of the large amount of caffeine they contain?

COLA
CHOCOLATE FLAVOR SYR
COFFEE
TEA
TEA

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 25-1 Drugs and Health
- How Drugs Affect the Body
- Tobacco
- Alcohol
- Caffeine

Section 25-2 Science and Society
Drugs in Society
- Costs of Drug Abuse

Section 25-3 Problems with Illegal Drugs
- Marijuana
- Stimulants
- Depressants
- Hallucinogens
- Opiates

Previewing Science Skills

- In the **Skill Builders,** you will make a concept map and outline.
- In the **Activities,** you will analyze, observe, and collect data.
- In the **MINI-Labs,** you will make a model and classify.

What's next?

Now you know that many foods, medicines, and drinks contain the drug caffeine. In this chapter, you will find out what effects caffeine and other drugs have on the body.

25-1 Drugs and Health

New Science Words

drug
drug misuse
drug abuse
psychological dependence
physical dependence
tolerance
withdrawal
stimulant
fermentation
depressant

Objectives

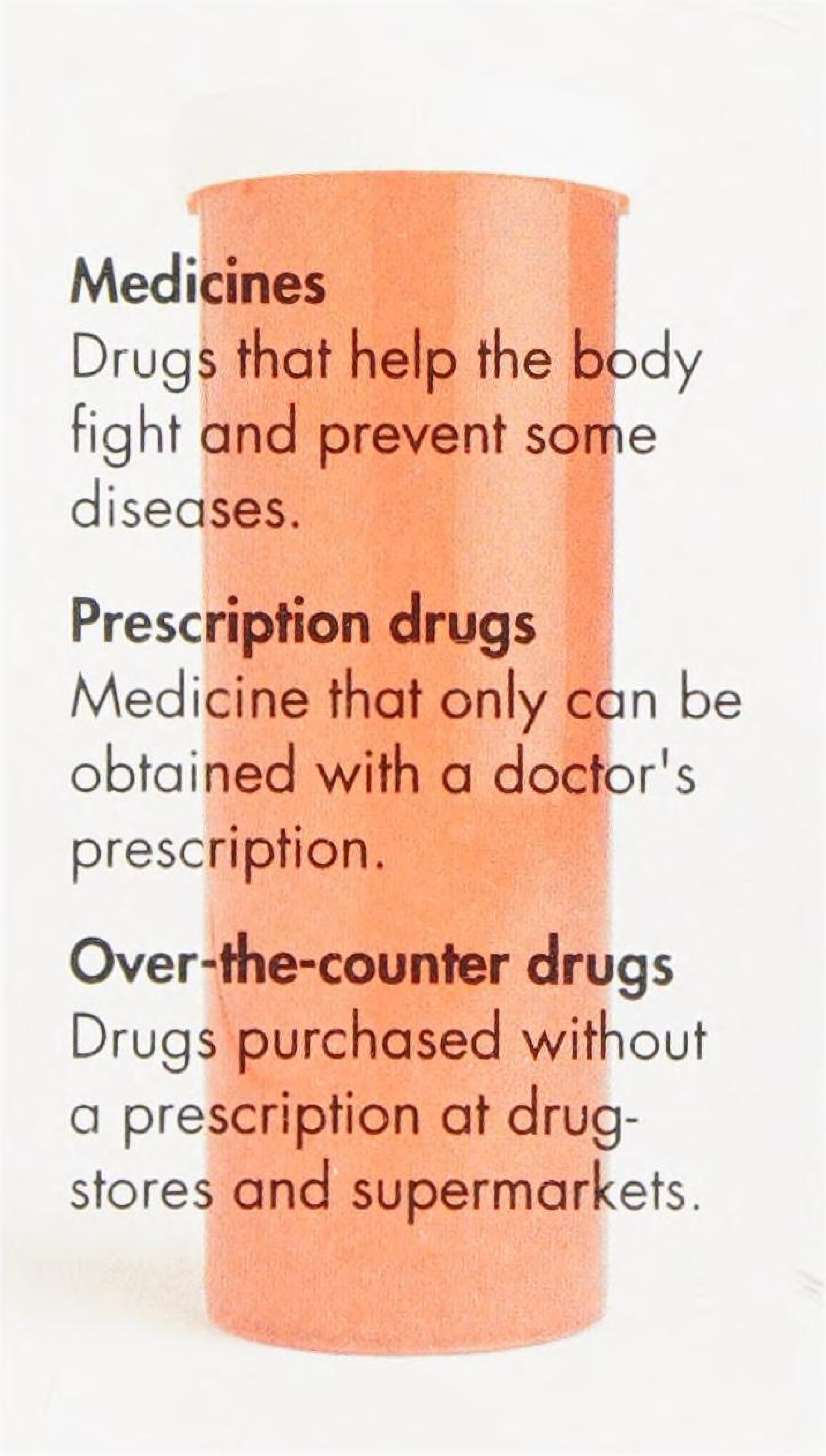
- Explain how drug misuse differs from drug abuse.
- Describe the effects of nicotine and alcohol on the body.
- Explain the effects of caffeine.

How Drugs Affect the Body

Make a list of five things that you think include drugs. Does your list include foods, drinks, tobacco, medicines, or illegal drugs? A **drug** is any chemical substance that changes the way a person thinks, feels, or acts. Drugs provide no nutrition for the body. Different drugs can act to slow down or speed up the nervous system or to change the functions of some cells. Most drugs are derived from plants, fungi, and bacteria.

When used properly, drugs benefit health. When used improperly, they can harm the user. For example, taking too much of some kinds of blood pressure medicine can lower blood pressure so much that a person feels faint. Improper use also can cause behavior that harms the health and safety of others. Driving after drinking can result in injury to the driver and others. Because of these concerns, federal laws were passed to control the manufacture, distribution, and possession of all drugs.

Have you ever been really sick with a cold and cough? Your doctor may have prescribed medicine with a cough suppressant to keep you from coughing so hard and to let you rest. Suppose you decided to take an extra spoonful before bedtime to make sure you were able to sleep all night. This behavior is a form of drug misuse. **Drug misuse** is use of a drug for the purpose for which it was made, but taking it improperly. Taking too much or too little medicine according to directions is drug misuse. Using someone else's medicine is also drug misuse. Drug misuse is harmful to health. **Drug abuse** is the deliberate use of a drug for other than its intended purpose. Using illegal drugs is drug abuse. Drug abuse damages a person's health.



Medicines
Drugs that help the body fight and prevent some diseases.

Prescription drugs
Medicine that only can be obtained with a doctor's prescription.

Over-the-counter drugs
Drugs purchased without a prescription at drugstores and supermarkets.

Figure 25-1. Many kinds of drugs are made for helping people regain health.

When drugs are misused or abused, serious health problems can result. A person can develop chemical dependence. With this condition, a person has a psychological and/or physical need for a drug. A person who has **psychological dependence** really believes that he or she needs the drug. The person may believe that use of the drug can be controlled. A person who has **physical dependence** has a chemical need for a drug. This also is called addiction. The person becomes so used to the effects of the drug that he or she needs it to function. There are two parts to physical dependence—tolerance and withdrawal. **Tolerance** occurs when the body adjusts to a drug and needs increasingly larger doses to produce the desired effect. **Withdrawal** is an illness that occurs when the drug a person is physically dependent on is removed. Withdrawal symptoms are real and can be very painful. They include nausea, vomiting, headaches, and chills.

What are the two parts to physical dependence?

TECHNOLOGY

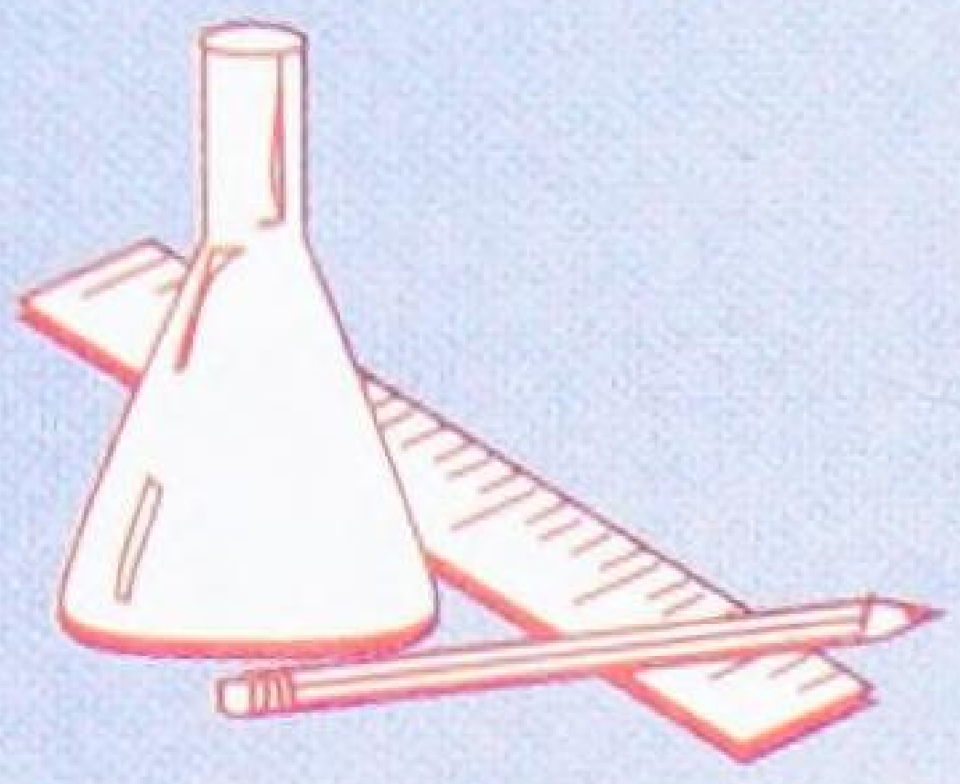
Taking Your Medicine

Some people need medicine or pain killers regularly. People with diabetes or cancer seem to respond best to frequent, low doses of medication. Taking medication by mouth can cause high blood levels of medicine as the medicine takes effect, followed by low blood concentrations as it wears off. This takes the patient on a roller coaster ride of pain or problems. Various techniques are being explored that allow a steady release medication system, flexible enough to allow a higher dosage on demand.

A drug pump may be implanted under skin and deliver medication as directed by a desktop programmer. A syringe-type pump is frequently used for newborns and for cancer patients. Other systems use biodegradable implants that slowly release medication as the implant breaks down. Ultrasound waves, magnetism, heat, and enzyme triggers are all being studied as ways of allowing patients to increase the dosage released by an implant.

Think Critically: What kinds of illness might this system be most useful for?

SYRINGE INFUSION PUMP
MODEL 2001
medfusion



ACTIVITY 25-1

Interpreting Drug Label Information

Problem: *What information is on the label of an over-the-counter drug?*

Materials

- paper
- pencil

Procedure

1. The photograph below shows a label from an over-the-counter drug. Read it carefully.
2. Make a data table like the one shown. Use the information on the label to complete the data table.

Data and Observations

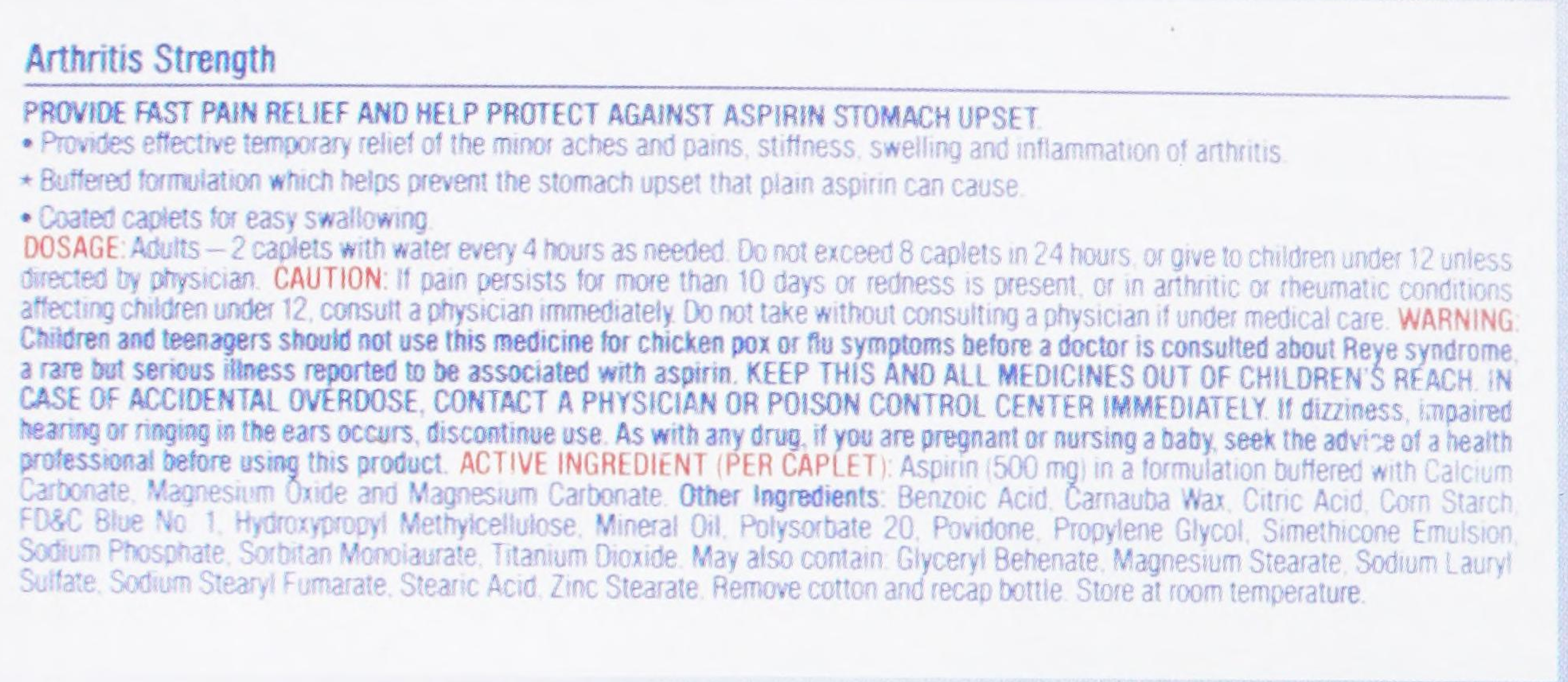
Information	Drug Label
Product	
Number of pills	
Ingredients in the medicine	
Directions for use	
Warnings	
Possible side effects	
Expiration date	
Storage of drug	

Analyze

1. What is an over-the-counter drug?
2. What is a side effect? What side effects are caused by this drug?
3. What information is given on the label of this over-the-counter drug?
4. For whom does the label specify the drug is intended?
5. Who should not take this drug without consulting a physician?
6. What is the maximum number of doses that should be taken in 24 hours?

Conclude and Apply

7. Explain how over-the-counter drugs differ from prescription drugs.
8. Why should a person never take any kind of drug without reading the label?
9. *Infer* why the age of a person would determine drug dose.
10. Why should a person never take more than the recommended amount of an over-the-counter drug?



Arthritis Strength

PROVIDE FAST PAIN RELIEF AND HELP PROTECT AGAINST ASPIRIN STOMACH UPSET.

- Provides effective temporary relief of the minor aches and pains, stiffness, swelling and inflammation of arthritis.
- Buffered formulation which helps prevent the stomach upset that plain aspirin can cause.
- Coated caplets for easy swallowing.

DOSAGE: Adults – 2 caplets with water every 4 hours as needed. Do not exceed 8 caplets in 24 hours, or give to children under 12 unless directed by physician. CAUTION: If pain persists for more than 10 days or redness is present, or in arthritic or rheumatic conditions affecting children under 12, consult a physician immediately. Do not take without consulting a physician if under medical care. WARNING: **Children and teenagers should not use this medicine for chicken pox or flu symptoms before a doctor is consulted about Reye syndrome, a rare but serious illness reported to be associated with aspirin.** KEEP THIS AND ALL MEDICINES OUT OF CHILDREN'S REACH. IN CASE OF ACCIDENTAL OVERDOSE, CONTACT A PHYSICIAN OR POISON CONTROL CENTER IMMEDIATELY. **If dizziness, impaired hearing or ringing in the ears occurs, discontinue use. As with any drug, if you are pregnant or nursing a baby, seek the advice of a health professional before using this product.** ACTIVE INGREDIENT (PER CAPLET): Aspirin (500 mg) in a formulation buffered with Calcium Carbonate, Magnesium Oxide and Magnesium Carbonate. **Other Ingredients:** Benzoic Acid, Carnauba Wax, Citric Acid, Corn Starch, FD&C Blue No. 1, Hydroxypropyl Methylcellulose, Mineral Oil, Polysorbate 20, Povidone, Propylene Glycol, Simethicone Emulsion, Sodium Phosphate, Sorbitan Monolaurate, Titanium Dioxide. May also contain: Glyceryl Behenate, Magnesium Stearate, Sodium Lauryl Sulfate, Sodium Stearyl Fumarate, Stearic Acid, Zinc Stearate. Remove cotton and recap bottle. Store at room temperature.

Tobacco

When a person first begins to smoke, he or she may feel sick. It takes time for the body to get used to nicotine, the drug in tobacco. Many people do not think of the nicotine in tobacco as a drug. However, it is a **stimulant,** a drug that speeds up the nervous system. Nicotine speeds up the heartbeat rate and raises blood pressure. It constricts blood vessels, reducing blood flow. Nicotine also contributes to the buildup of fatty substances in blood vessels. The chance of developing blood clots that cause heart attacks and strokes increases. Nicotine causes physical and psychological dependence.

Tobacco smoke brings other substances into the body. Carbon monoxide is a harmful gas found in tobacco smoke. Carbon monoxide becomes attached to hemoglobin in red blood cells more easily than does oxygen. The hemoglobin cannot carry oxygen. As a result, cells do not get enough oxygen. The respiratory and cardiovascular systems have to work harder.

In Chapter 21, you read that tar is a thick, sticky fluid produced when tobacco burns. Tar sticks to the respiratory tract. It damages cilia and contains cancer-causing chemicals.

In Your JOURNAL

More than 300’ 000 people die each year in the United States due to smoking. In spite of the fact that many people have stopped smoking, more cases of lung cancer are being reported. It takes 20 to 30 years for lung cancer to develop. Many people who stopped smoking in the 1960s were diagnosed with cancer only in the 1980s. Why smoke cigarettes? *Analyze* tobacco advertisements. **In your Journal,** describe techniques used by cigarette manufacturers to suggest smoking a particular brand.

PROBLEM SOLVING

Passive Smoke

Tim and his family were eating in the nonsmoking section of a restaurant. However, when Tim began to eat, smoke from a burning cigarette in the smoking section wafted under his nose. It affected the taste of Tim's food. He was upset that his dinner was being disturbed by this smoke. Tim knows that nonsmokers who are exposed to tobacco smoke from cigarettes or smoke exhaled by a smoker have an increased risk of developing the same diseases as those who smoke. What would you have done if you were Tim's family?

Think Critically: Tim thinks smoking shouldn't be allowed in public places. What do you think about smoking in public places?

NO SMOKING SECTION

Unfortunately, you cannot escape the danger of tobacco smoke by just not smoking. There are real health risks from just being in a room with tobacco smoke. If you are in a room with someone who is smoking, harmful substances from smoke will enter your respiratory system. The smoke from a burning cigarette, cigar, or pipe is known as passive smoke. Passive smoke contains more tar, nicotine, carbon monoxide, and other chemicals than that inhaled by the smoker.

MINI-Lab

A Childproof Package?

Survey different types of packaging used in over-the-counter drugs to make them tamperproof and childproof. *Design* a childproof package for a product. Could your package be opened easily by a person with arthritis?

Alcohol

Alcohol is also a drug. Alcoholic drinks have been made and used in most cultures since ancient times. The sugar in fruits and grains reacts with yeast to produce alcohol and carbon dioxide in a process known as **fermentation.**

Most alcohol is absorbed through the walls of the stomach and small intestine. It enters the circulatory system undigested. Carried by the blood, all body tissues become exposed to it directly. Alcohol is often viewed as a stimulant, but it is a **depressant.** As such, alcohol changes the function of cell membranes, slows down the central nervous system, and affects all functions of the brain. Judgment, reasoning, memory, and concentration are impaired. Muscle functions are affected. Even though alcohol is a depressant, it slightly increases heartbeat and pulse rate. It causes blood vessels to enlarge. As a result, a feeling of warmth passes through the body. In reality, however, the body is losing heat from the capillaries near the surface of the skin. Heavy use of alcohol results in destruction of brain and liver cells.

Connect to...

Physics

Depressants cause changes in the nervous system. In some extreme cases, the heart stops beating. What happens to the principle of diffusion at a synapse when a depressant drug is present?

Large amounts of alcohol in the bloodstream dull the senses and cause the drinker to have a slower reaction time, lose coordination, and have slurred speech. Excessive amounts of alcohol can result in unconsciousness and death.

Most states have laws that define when a person is legally drunk, based on levels of alcohol in the person's blood. The amount of alcohol that causes abnormal behavior and loss of judgment varies considerably from person to person. Some people react after one drink.

Sometimes, people become physically dependent on alcohol. Alcoholism is an incurable disease characterized by the abuse of alcohol. The person with this disease cannot control his or her drinking. Continued use of alcohol causes permanent damage to all body cells. Alcoholism also causes personality and behavioral changes. These problems affect the alcoholic and others around him or her. Approaches used to treat alcoholism include drugs, therapy, and self-help programs.

In Your JOURNAL

Find out about the programs of Alcoholics Anonymous, Al-Anon, and Alateen. Describe the work of these groups **in your Journal** and share the information with the class.

Caffeine

What do coffee, tea, and cola soft drinks have in common? You probably know that it is the drug caffeine. Caffeine is a stimulant, a type of drug that stimulates your central nervous system and speeds up other body systems. You may hear people say they need a cup of coffee to get started in the morning or a cola soft drink for energy in the afternoon. They may be dependent on the caffeine in the drink to feel more energetic. Caffeine also is found in chocolate and cocoa. It is probably the most used stimulant in the world because it is so readily available.

Too much caffeine can increase heartbeat rate and cause a person to be restless, have tremors, and be unable to sleep. It can also stimulate the kidneys to produce more urine. Caffeine can cause physical dependence. When people who take in a lot of caffeine stop, they can have headaches and nausea. In spite of these known effects, a study released in 1990 showed that no damage could be found from the use of caffeine products. The study followed the caffeine habits of more than 10 000 people for a period of more than five years.

SECTION REVIEW

1. How does drug misuse differ from drug abuse?
2. How does nicotine affect the body?
3. How does alcohol affect the brain?
4. What happens when a person consumes too much caffeine?
5. **Apply:** Why does constant alcohol use cause permanent damage to blood vessels?
6. **Connect to Chemistry:** What does *transdermal* mean? Find out how transdermal patches work.

Concept Mapping

Skill Builder

Using a network tree concept map, show some differences between depressants and stimulants discussed in this section and give examples. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

SCIENCE & SOCIETY

25-2 Drugs in Society

New Science Words

methamphetamine

Objectives

- Explain the cost of drug abuse to society.
- List two attempts that have been made to solve the problem of drug abuse.

Costs of Drug Abuse

For some time, drug abuse has been America's greatest concern. Many people suffer because of the effects of illegal drugs. In 1989, 2500 people in the United States died as a result of drug overdoses, drug-related crimes, or drug-related accidents. Babies born to mothers that abuse drugs may be addicted and suffer effects of the drugs. In the business world, of 1000 corporate executives surveyed, 67 percent agreed that drug abuse is the nation's number one labor problem. Loss of productivity, industrial accidents, higher health care cost, absenteeism, and lateness due to employee drug abuse results in $160 billion in business loss each year. The General Motors Corporation reports that it loses $1 billion each year to employee drug abuse. Indirectly, this loss is then added to the price of new cars.

Quit it.
Call 1-800-662-HELP

Figure 25-2. Campaigns to stop drug abuse are visible in many places.

How can these problems be solved? In 1982, a war on drugs was declared in the United States. It was designed to attack the problem of drug abuse by educating the general public about the effects of drugs. Law enforcement was strengthened through increased crackdowns on dealers, expanded courts and prisons, and even military forces to keep drugs out of the country. The program appears to have had some impact on the problem. But despite attempts to prevent illegal drugs from entering the United States, drugs continue to arrive. The 60 to 75 percent drop in the prices of some drug on the streets shows how easily available drugs are. What is the real source of the drug problem? Is it lack of education?

Connect to... Chemistry

Find examples of the following types of drugs that are used often in an abusive manner: prescription drugs, and legal, non-prescription drugs.

In South America, it is estimated that millions of hectares of land are used to grow the coca plant from which cocaine is produced. Even if this crop were destroyed, experts predict that addicts would produce a synthetic cocaine to satisfy their needs. This has already happened in the United States. A very powerful drug called **methamphetamine** (meth am FET uh men), crank, or ice speeds up body functions. Its effects last up to eight hours. Do drug suppliers provide their product because they know they will always have customers?

Some people argue that there is no solution to controlling the drug abuse problem in the United States. Drug education programs and increased law enforcement have proven effective for some, but not for all. It may be a while before the positive effects of drug education can be seen. Some experts suggest that drugs should be legalized. They suggest that the war on drugs is not practical because millions of Americans are paying for failed attempts to capture and reform hard-core drug producers. After all, alcohol and caffeine are legal. As law enforcement gets tougher, dealers may only make the drugs stronger, easier to hide, and more dangerous. What would happen if these drugs were made legal? How do you think the rate of abuse would change?

Figure 25-3. Drugs exist to help, not to be abused.

SECTION REVIEW

1. Why does drug abuse cause such a great loss to businesses each year?
2. List ways in which the government attempted to declare war on drugs to help solve the problem of drug abuse.

SCIENCE & SOCIETY

You Decide!

How much publicity do drugs receive? Many magazines, movies, and television programs still make drug use appear glamorous. Even tobacco and alcohol ads make it appear that people who use these products are young, well-dressed, and always having a great time. Does advertising give the wrong impression? What can be done to make people understand the truth about drugs?

25-3 Problems with Illegal Drugs

New Science Words

marijuana
hashish
cocaine
crack
hallucinogens
heroin

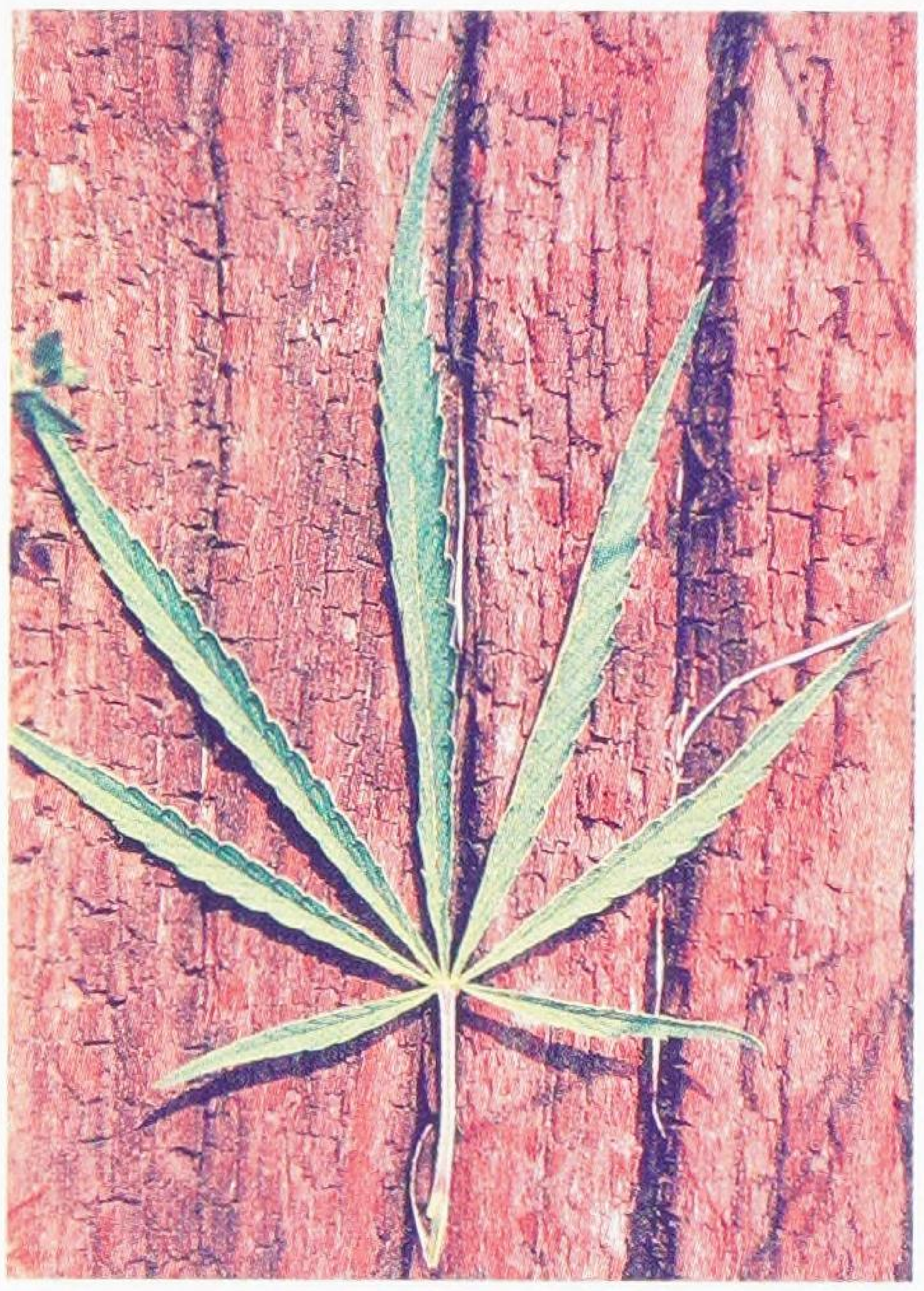


Figure 25-4. Marijuana is made from the parts of the hemp plant.

Objectives

- Compare the effects of marijuana and tobacco use.
- Describe the effects of stimulants and depressants.
- Describe the effects of hallucinogens.
- Explain problems of using opiates.

Marijuana

Indian hemp is a weed plant found worldwide. An illegal drug called **marijuana** or pot is made from the stems, leaves, flowers, and seeds of this hemp plant. These plant parts are crushed up and made into a cigarette (joint) for smoking. The sticky tarlike substance from the flowering top of the marijuana plant is known as **hashish.** This is more concentrated and powerful than marijuana. Hashish is smoked, chewed, or put in a drink to get its effect.

Marijuana is considered to be more dangerous than cigarettes. Many harmful chemicals have been identified in marijuana. The most powerful is THC, which produces a mind-altering effect. The effects of marijuana use depend a lot on the user's surroundings and feelings at the time it is smoked. It can both stimulate and depress. The person who uses marijuana may feel calm, relaxed, and have a feeling of well-being. Then the user may become sensitive to sights and sounds. Marijuana use impairs reaction time and coordination. It harms a person's ability to think, learn, and remember. The effects of smoking marijuana last from two to four hours. Regular users can suffer long-term effects, including losing interest in life. They substitute marijuana for other goals. They also experience feelings of anxiety, panic, and periods of depression.

Marijuana use has physical effects as well. Smoking the drug increases heartbeat rate and therefore is dangerous for persons with heart conditions. Its effects on the lungs are similar to those of tobacco use. Lung tissue can be damaged. The risks of bronchitis, emphysema, and lung cancer increase.

Even though marijuana does not cause physical dependence, users want the good feeling to continue. They develop a psychological dependence on the drug.

Stimulants

What effect do stimulants have on the body?

As you read earlier, nicotine and caffeine are stimulants. However, there are much stronger stimulants than those. One group of stimulants is amphetamines (am FET uh meenz). In the past, amphetamines were prescribed to increase a person's energy and decrease appetite to control weight. This is rarely done now.

Illegal amphetamines are known as pep pills and uppers. Another form of illegal amphetamines is known as speed or crank. Crank is also called ice. These drugs suppress hunger and cause the user to experience increased energy. Their use increases heartbeat rate, blood pressure, and breathing. Used over a long period of time, these drugs can lead to anxiety and feelings that someone will cause the person harm. Physical and psychological dependence can result. Withdrawal from use of these drugs can cause depression.

Another illegal stimulant is **cocaine,** a white powder made from the leaves of the South American coca plant. It is thought that the leaves of the coca plant are chewed by workers in the Andes Mountains to stimulate their bodies in this low-oxygen environment. Cocaine was an ingredient in many nonprescription drugs in the 1800s. A popular cola soft drink originally had cocaine in it and was advertised as a stimulant.

Cocaine is inhaled through the nose, swallowed, or injected. It is absorbed by membranes and enters the bloodstream quickly. Cocaine is a drug that users can become dependent on in a matter of days. The drug has a short-lived "high," or feeling of well-being. Anxiety soon replaces the good feeling. To get the same feeling, a user must take increasingly larger doses of the drug. Cocaine increases heartbeat rate and blood pressure and has been associated with sudden death due to a heart attack.

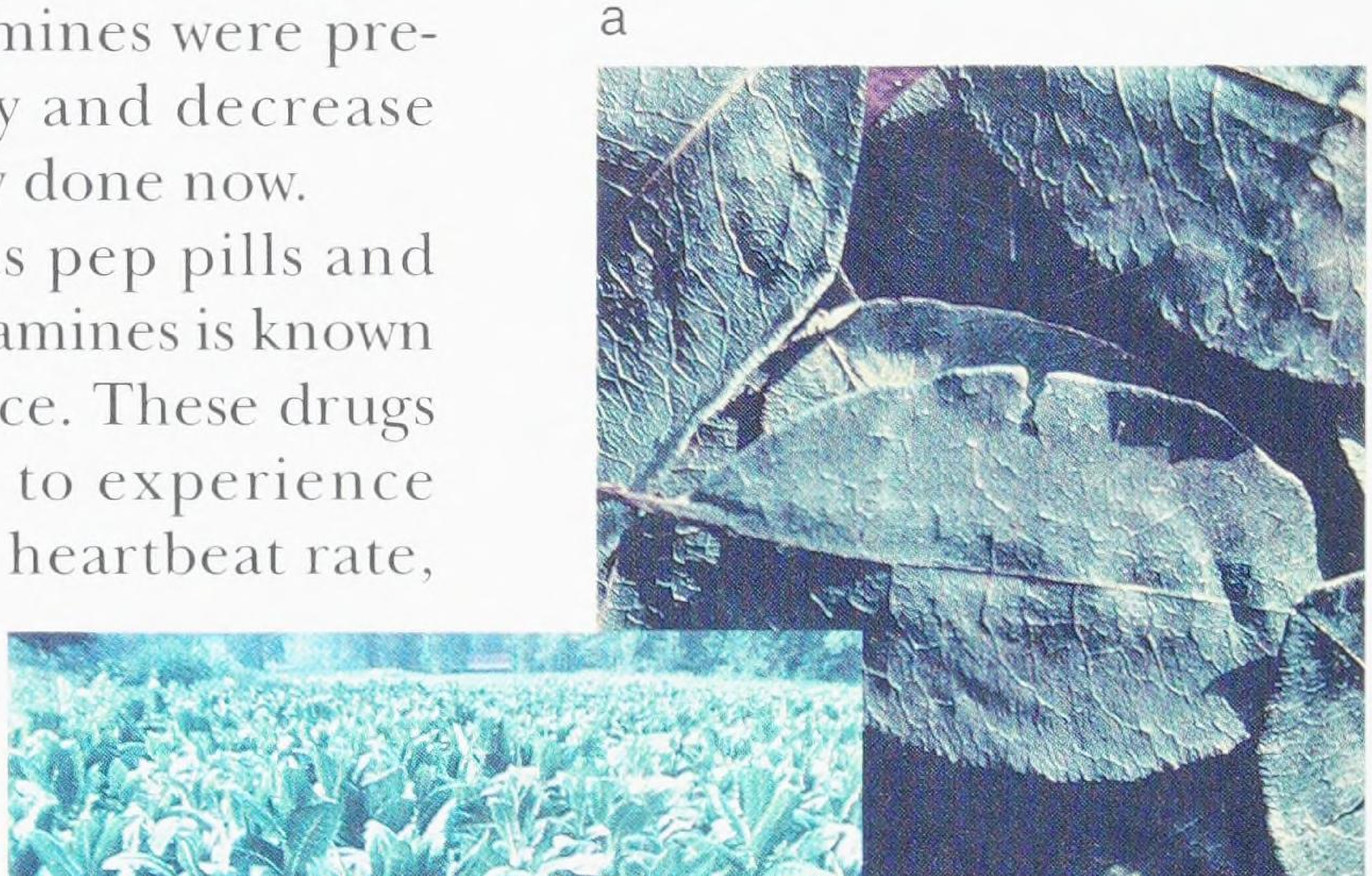


Figure 25-5. Coca leaves (a), tobacco (b), and coffee (c) contain substances that stimulate the body to different degrees. The stimulants produced from coca leaves are controlled, illegal substances.

A stronger form of cocaine is called **crack.** Crack is a smokable form of cocaine. Since the introduction of crack around 1986, it has rapidly become a much abused drug. Unfortunately, many people did not realize the rapid addictive powers of cocaine or its dangerous effects on the body. The effects of crack are more intense and short-lived than cocaine. As with all stimulants, the drug affects the central nervous system. Crack use causes constricted blood vessels, causing the heart to work harder to move blood throughout the body. As a result, blood pressure increases, and an irregular heartbeat can develop. Heart failure can occur. The initial high of the drug is followed by a period of depression in which the user may feel anxious and irritable and have a strong craving for more of the drug. Pregnant females using the drug pass the drug through the placenta to the developing fetus. These babies can develop physically dependent. After birth, these babies go through withdrawal.

How does crack affect the body?

Depressants

You read earlier about depressants, drugs that slow down the central nervous system. Alcohol, sleeping pills, tranquilizers, and a class of drugs called barbiturates (bar BIH chuh ruts) are all depressants. A slang word for depressant pills is "downers." Depressants slow down or prevent impulses from moving across a synapse from one neuron to another. How would this affect your heart and your respiratory system? Blood vessels dilate and blood pressure lowers. Breathing rates slow. A person under the influence of depressants may be confused, lack coordination, appear to be intoxicated, and have slow reflexes. This person is prone to accidents.

Figure 25-6. Taking combinations of depressants can be deadly.

An overdose of depressants can cause coma, depressed breathing, uncontrolled muscle spasms, and eventually death. Depressants taken in combination with other depressants, such as sleeping pills or alcohol, increase the dangerous effects. Withdrawal from depressants is difficult.

Some persons take a combination of stimulants and depressants to try to keep in a constant state of drug enjoyment. The physical and psychological damage to the body is severe and can lead to death.

Hallucinogens

Hallucinogens (huh LEWS un uh junz) are a group of drugs that affect users' perceptions and consciousness of the world around them. Under the influence of hallucinogens, the user often experiences an extreme sensitivity to light, sound, taste, and odor. This causes confusion, and the person cannot tell the difference between reality and fantasy.

In addition to psychological dependence, the use of hallucinogens can cause a person to have unpredictable, violent behavior. Coma, convulsions, and death can occur with the use of these drugs.

Two of the more powerful hallucinogens are LSD and PCP, also called angel dust. These drugs can produce dramatic effects from taking even small amounts. The senses become highly stimulated, and users talk about "seeing" sounds, "tasting" odors, and "hearing" colors. The effects may last for several hours. The hallucinations of a bad experience with these drugs can cause anxiety and panic and lead to suicide. LSD is also known to cause flashbacks to hallucinations that occurred years before.

The use of hallucinogens can bring about dramatic changes in personality. Persons who use these drugs find they can't control themselves after using even a small amount. Users may react violently toward themselves or others. In some cases, they may slip into a long, semiconscious state. The results of using these drugs are unpredictable.

Connect to...
Chemistry

Ergot is a parasitic fungus that grows on rye and some other plants that are classified as grasses. It contains LSD. What condition does it stimulate? What are its symptoms?

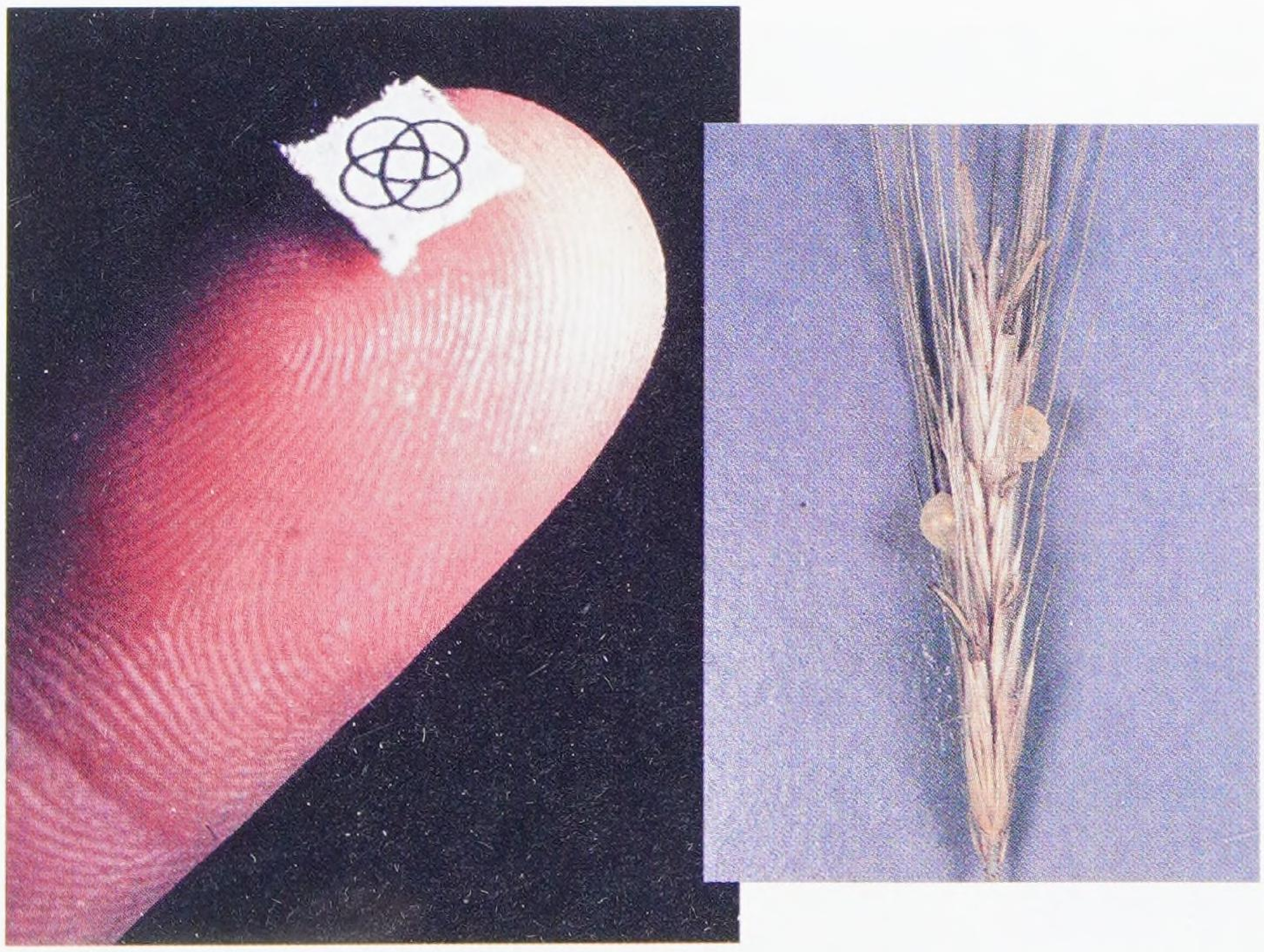


Figure 25-7. Even small amounts of LSD, such as those found in the small patch to the left, can cause hallucinogenic responses. The photograph on the right shows ergot on a head of rye grain.

Opiates

In Your JOURNAL

An analgesic is a drug that relieves pain. Aspirin and morphine are both analgesics. So is acetaminophen. **In your Journal,** explain why some people cannot take aspirin.

Using plant substances to relieve pain has occurred often throughout history. During the third century B.C., the Greeks used a substance from the white poppy to relieve suffering from pain. This same substance was introduced to the Orient in the 1800s. However, the drug soon was used less for medical purposes than for putting oneself into a dreamlike state. Physical dependence on the drug became widespread. This drug was opium, made from the juices of the seed capsule of the white poppy. Opium and its active chemical, morphine, were used as pain killers during the Civil War. Many wounded soldiers became dependent on morphine. Because there were no laws regulating nonprescription drugs, many of them also contained opium or morphine. People became physically dependent on these medicines. There was such a protest against the use of these drugs, that Congress passed the Pure Food and Drug Act in 1906. This law required that labels on medicine show whether they contain alcohol, opium, or morphine.

What does the Pure Food and Drug Act require?

Because morphine was a good pain killer but could cause physical dependence, researchers tried to make other pain-relieving drugs from opium. The powerful drug **heroin** was made from morphine. It was not supposed to cause physical dependence. However, this was not true. A much stronger drug than morphine, heroin is one of the most addictive drugs and is widely abused in the United States.

Figure 25-8. Morphine is used medically as a pain reliever after some surgeries and for some terminal cancer patients. Its use is strictly regulated.

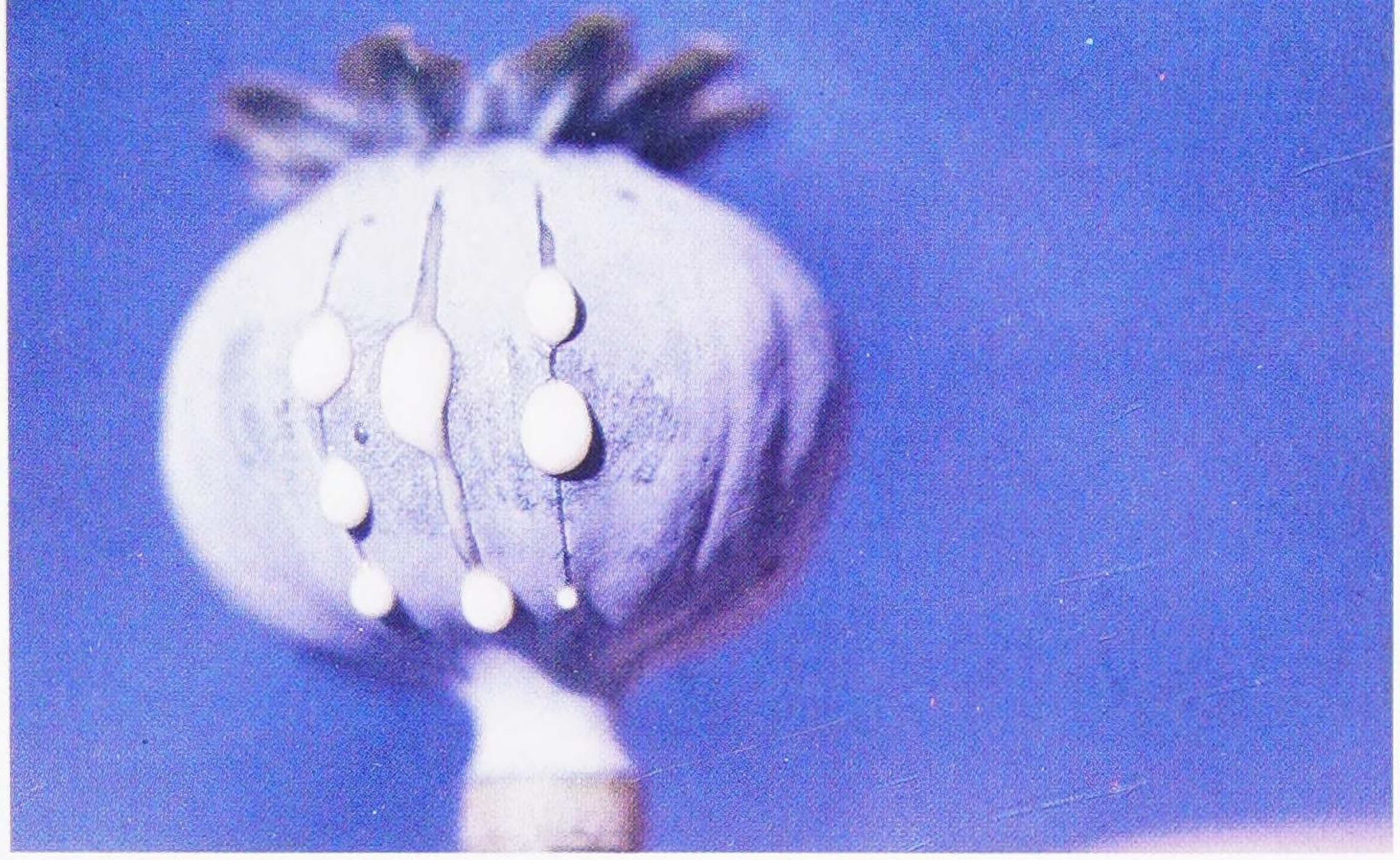


Figure 25-9. Opium is made from the juices of the seed capsule of the white poppy.

Opiates, also called narcotics, cause a brief, dreamlike state, drowsiness, constricted pupils, and nausea. Because these drugs are often injected and the needles shared, users can develop infections from contaminated needles. Tetanus; hepatitis (hep uh TITE us), a disease of the liver; and HIV are spread among heroin users when sharing needles to use the drug.

Drug abuse has become one of the greatest problems in our country today. The waste of human resources and lives due to drug abuse has affected every community. Sometimes, people feel the only way to escape their problems is to use drugs. Unfortunately, by doing this they exchange one set of problems for another. Problems of drug dependence lead to mental and physical illness and sometimes death. There is no future in drug abuse.

MINI-Lab

How are drugs classified?

Make flash cards for the following drugs. *Classify* them into categories of stimulants, depressants, hallucinogens, and opiates. Drugs: alcohol, amphetamines, barbiturates, crank/ice, caffeine, cocaine, crack, LSD, heroin, morphine, PCP, sleeping pills, speed, tranquilizers.

SECTION REVIEW

1. How is marijuana use similar to tobacco use?
2. Why are stimulants and depressants dangerous?
3. What are the dangers to a person's health if hallucinogens are used?
4. What are additional risks of using narcotics besides the effect of the drugs?
5. **Apply:** Why is it dangerous for a person who has been using marijuana to drive?
6. **Connect to Chemistry:** Find out what flashbacks are and why they can occur after use of a hallucinogen.

Outlining

Skill Builder

Outline the effects of two drugs discussed in Section 25-3. Title your outline, Problems with Illegal Drugs. If you need help, refer to Outlining in the **Skill Handbook** on page 681.

ACTIVITY 25-2

The Effect of Drugs on Heartbeat Rate

Problem: *How do drugs affect the heartbeat rate of an animal?*

Materials

- dilute solutions of coffee, cola, ethyl alcohol, tobacco, and cough medicine (dextromethorphen hydrobromide)
- *Daphnia* culture
- microscope
- dropper
- aged tap water

Procedure

1. Use a dropper to place a single *Daphnia* crustacean on a culture slide.
2. Place the slide under the microscope. Use low power and count the number of times the heart of the *Daphnia* beats in one minute. (See photo for location of the animal's heart.) Record your observations in a table like the one shown.
3. *Predict* whether the drugs are stimulants or depressants.
4. Add two drops of one of the drug solutions to the *Daphnia* in the culture dish.
5. Count the heartbeat rate again. Record your observations.
6. Use a dropper to remove the solution. Flush the slide and *Daphnia* carefully with aged tap water. **CAUTION:** *Flush the used* Daphnia *into a beaker of aged tap water provided by your teacher.*
7. Repeat Steps 1 through 6 for each of the drug solutions provided. **CAUTION:** *Use a new* Daphnia *for each step.*
8. Record the effects of each drug on heartbeat rate.

Analyze

1. What was the control in the experiment? What were the variables?

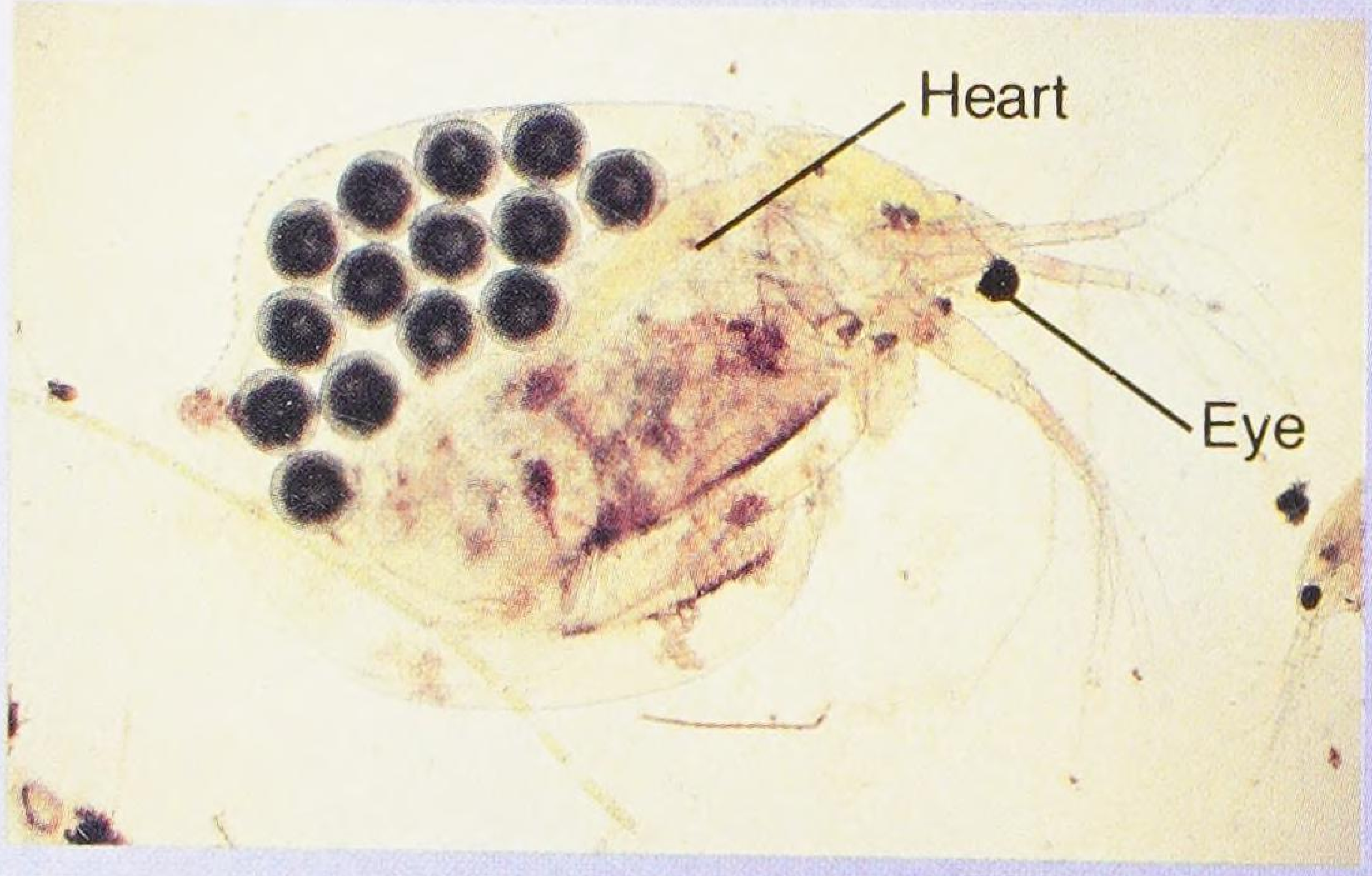
Data and Observations

Drug solution	Heart rate per minute	Stimulant or depressant
No drug		
Coffee		
Cola		
Ethyl alcohol		
Tobacco		
Cough medicine		

2. How did the drugs affect *Daphnia*?
3. Which drugs caused the greatest change in the number of heartbeats per minute?

Conclude and Apply

4. Which drugs are stimulants?
5. Which drugs are depressants?
6. Compare your predicted results with the experimental results.
7. How do drugs affect the rate of heartbeat of an animal?
8. How do you think the drugs used in this activity affect people who use them?



CHAPTER REVIEW

SUMMARY

25-1: Drugs and Health

1. Drug misuse is using a drug for the purpose it was made, but taking it improperly. Drug abuse is use of a drug for other than its intended purpose. Both are harmful to health and can cause chemical dependence.

2. Nicotine in tobacco speeds up the heartbeat rate; alcohol slows down body processes.

3. Caffeine is a stimulant.

25-2: Science and Society: Drugs in Society

1. Drug abuse costs can be measured in increased health care costs, on-the-job losses, and the cost of educating people on why they should avoid usage.

2. Education, increased law enforcement, and cooperation of countries from which drugs come are attempts to solve the drug problem.

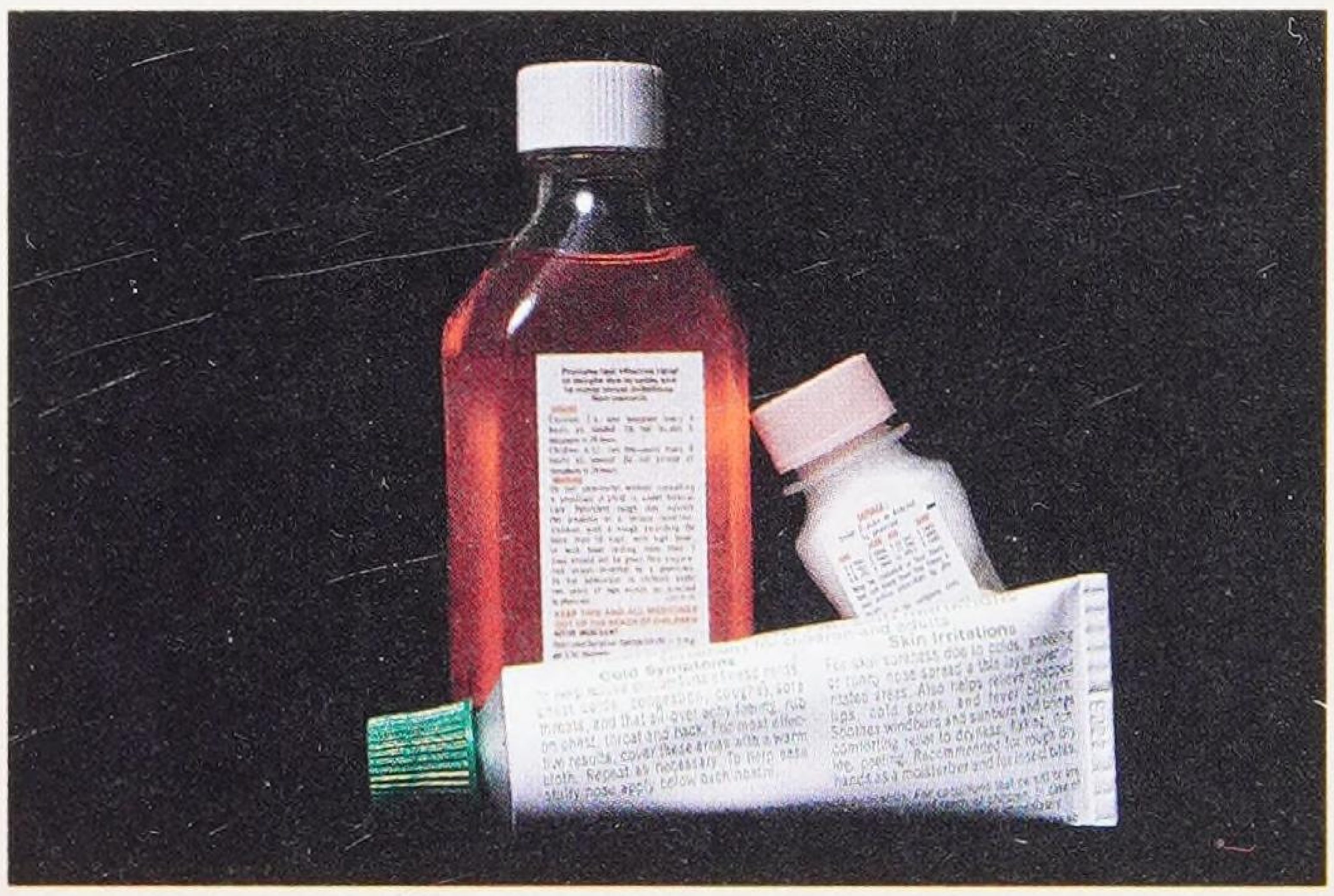
25-3: Problems with Illegal Drugs

1. Marijuana is more dangerous than cigarettes; marijuana produces a mind-altering effect.

2. Stimulants, including amphetamines, cocaine, and crack speed up body functions; depressants, including alcohol, tranquilizers, and barbiturates slow down body functions.

3. Hallucinogens affect perception and consciousness; users can react violently.

4. Opiates, such as morphine and heroin are narcotics and are very addictive.



KEY SCIENCE WORDS

a. **cocaine**
b. **crack**
c. **depressant**
d. **drug**
e. **drug abuse**
f. **drug misuse**
g. **fermentation**
h. **hallucinogens**
i. **hashish**
j. **heroin**
k. **marijuana**
l. **methamphetamine**
m. **physical dependence**
n. **psychological dependence**
o. **stimulant**
p. **tolerance**
q. **withdrawal**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. larger doses are needed to produce the effects of the drug
2. stronger form of cocaine
3. taking too much medicine
4. made from sticky residue of marijuana plants
5. using illegal drugs
6. process of making alcohol
7. drug that slows the body down
8. affect perception and consciousness
9. narcotic made from morphine
10. drug that increases heartbeat rate and breathing

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. Methamphetamine is also called _______.
   a. marijuana c. ice
   b. heroin d. crack
2. Alcohol is absorbed directly into the _______.
   a. heart c. large intestine
   b. stomach d. liver
3. The drug _______ is found in tobacco.
   a. tar c. carbon monoxide
   b. nicotine d. hashish
4. Smoking affects all of these body parts except _______.
   a. heart c. lungs
   b. blood vessels d. bones
5. _______ is an example of a depressant.
   a. Alcohol c. Caffeine
   b. Nicotine d. Amphetamine
6. An example of a stimulant is _______.
   a. LSD c. marijuana
   b. alcohol d. amphetamines
7. Symptoms of depressants include all of the following except _______.
   a. slow reflexes
   b. lowered blood pressure
   c. dilated blood vessels
   d. increased heartbeat rate
8. _______ is obtained from the white poppy.
   a. Caffeine c. Opium
   b. Marijuana d. LSD
9. An example of a narcotic is _______.
   a. alcohol c. PCP
   b. caffeine d. opium
10. A majority of drugs are obtained from _______.
   a. plants c. soil
   b. animals d. minerals

USING LAB SKILLS

11. In the Activity on page 582 the label of an over-the-counter aspirin was analyzed for information. Obtain the label of over-the-counter diet pills. What cautions are given about their use? Can they be dangerous?
12. In the MINI-Lab on page 584 you were asked to design a childproof package for a product. How would you design a childproof cap for a pill bottle that can be opened by persons with arthritis in their hands?

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. What is the difference between psychological and physical dependence?
14. What can happen to her baby if a pregnant female uses crack?
15. Explain why drug use is strictly controlled by the government.

APPLY

16. What are some effects on the body that are common to all stimulants?
17. What are some effects on the body that are common to all depressants?
18. Explain how industry is affected by drug abuse.
19. What differences would the way a drug is taken have on its effects?
20. Explain the physical effects of one drug discussed in this chapter.

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Comparing and Contrasting:** In a chart, compare and contrast the effects of stimulants and depressants.
2. **Making and Using Graphs:** Use the data from Activity 25-2 (page 594) to make a bar graph of substances and their effect on heartbeat rate in *Daphnia*.
3. **Hypothesizing:** Make a hypothesis as to what effects might be felt by a person who is smoking a cigarette and drinking coffee at the same time.
4. **Interpreting Scientific Illustrations:** Compare adult's dosage with child's on the label in Activity 25-1 (page 582). Why do you think a child's dose is different from an adult's?
5. **Concept Mapping:** Choose a brand name headache remedy and a generic brand. Compare the ingredients, cost, and amount of medication in each container. Make a network tree concept map showing your results.

PROJECTS

1. For one week, collect newspaper articles that have drug-related information in them. Bring these articles to school to share and discuss with your class.
2. Research the pattern of smoking habits among people in the United States over the past ten years. Who smokes more, men or women; what age group; how much do people smoke?

just say no
just say no
just say no
just say no

UNIT 7

GLOBAL CONNECTIONS

Staying Healthy

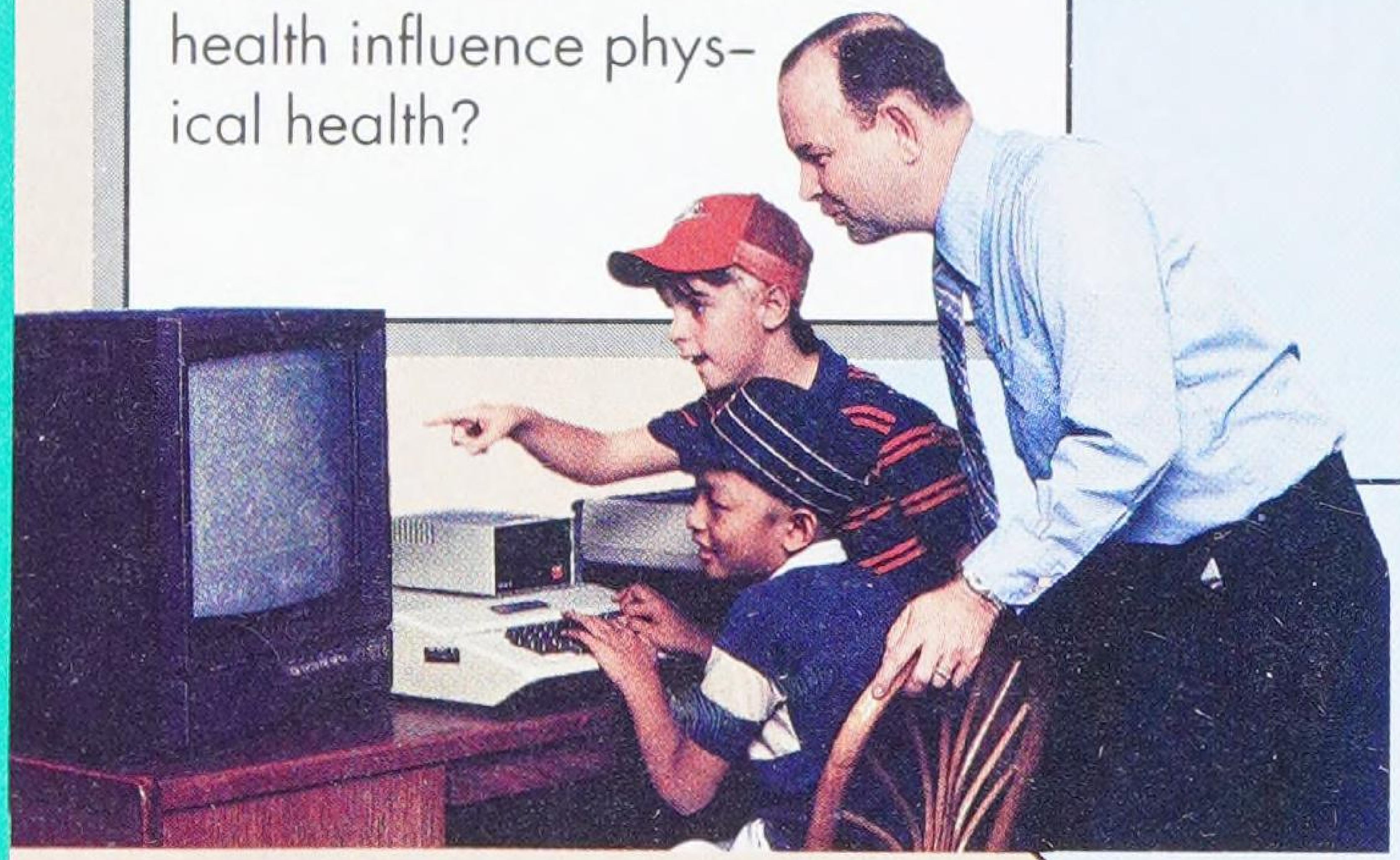
In this unit, you have studied health, disease, and drugs. Why is health important to all people? What influence does health have worldwide?

HEALTH

ZAPPING GERMS MAY HELP CURE DISEASE

Houston, Texas

A positive mental attitude may help cure diseases of the immune system. Patients at the M.D. Anderson Hospital can use a video game to zap germs. Fun may be an important part of the cure. How can mental health influence physical health?



HISTORY

BAD WATER EQUALS BAD HEALTH

London, England

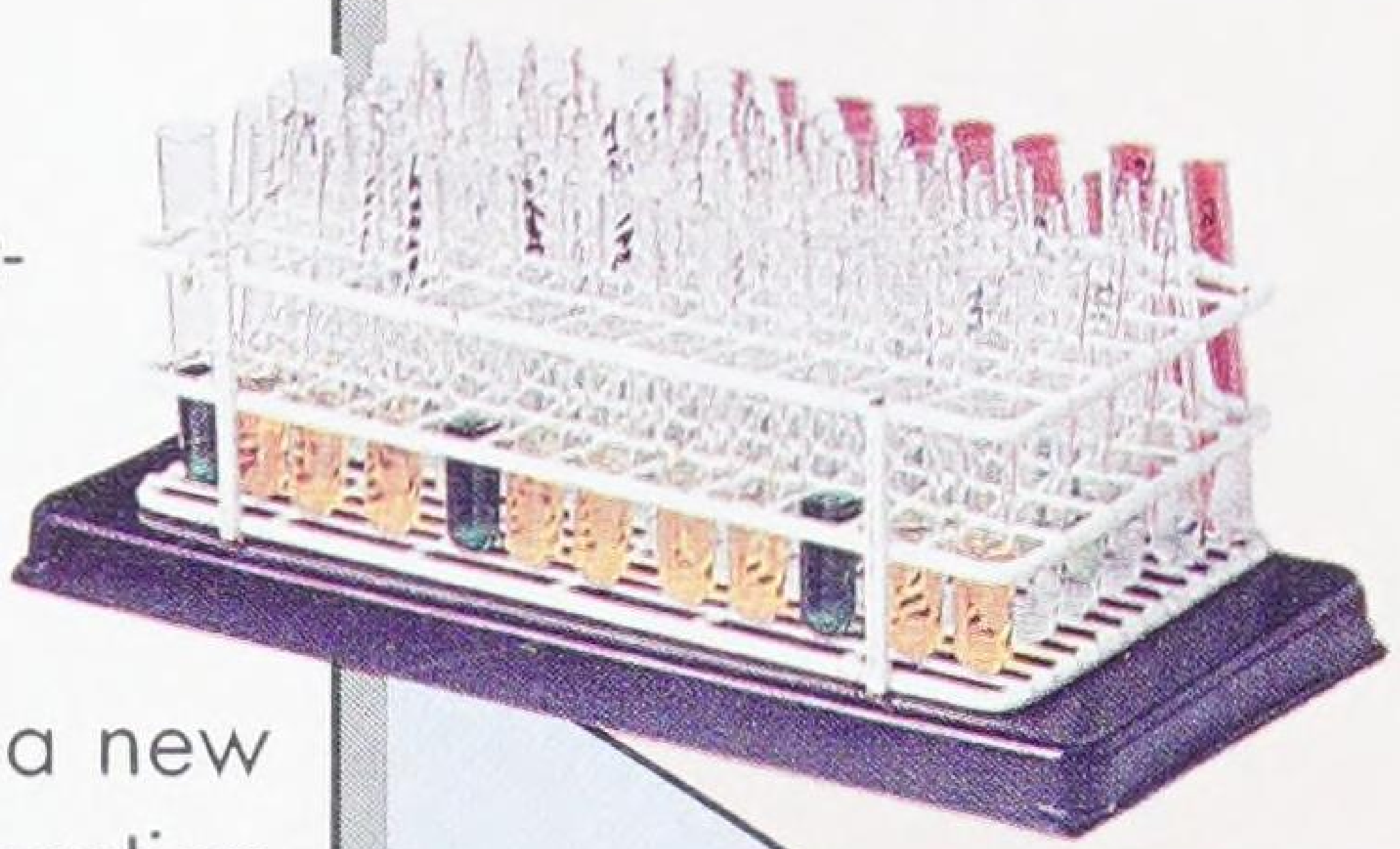
In 1854, more than 500 people from the same neighborhood died of cholera in less than a week. Why? Dr. John Snow found that they all got their water from the same well. When the well was closed, the epidemic stopped. Why is it important to have a source of clean water?

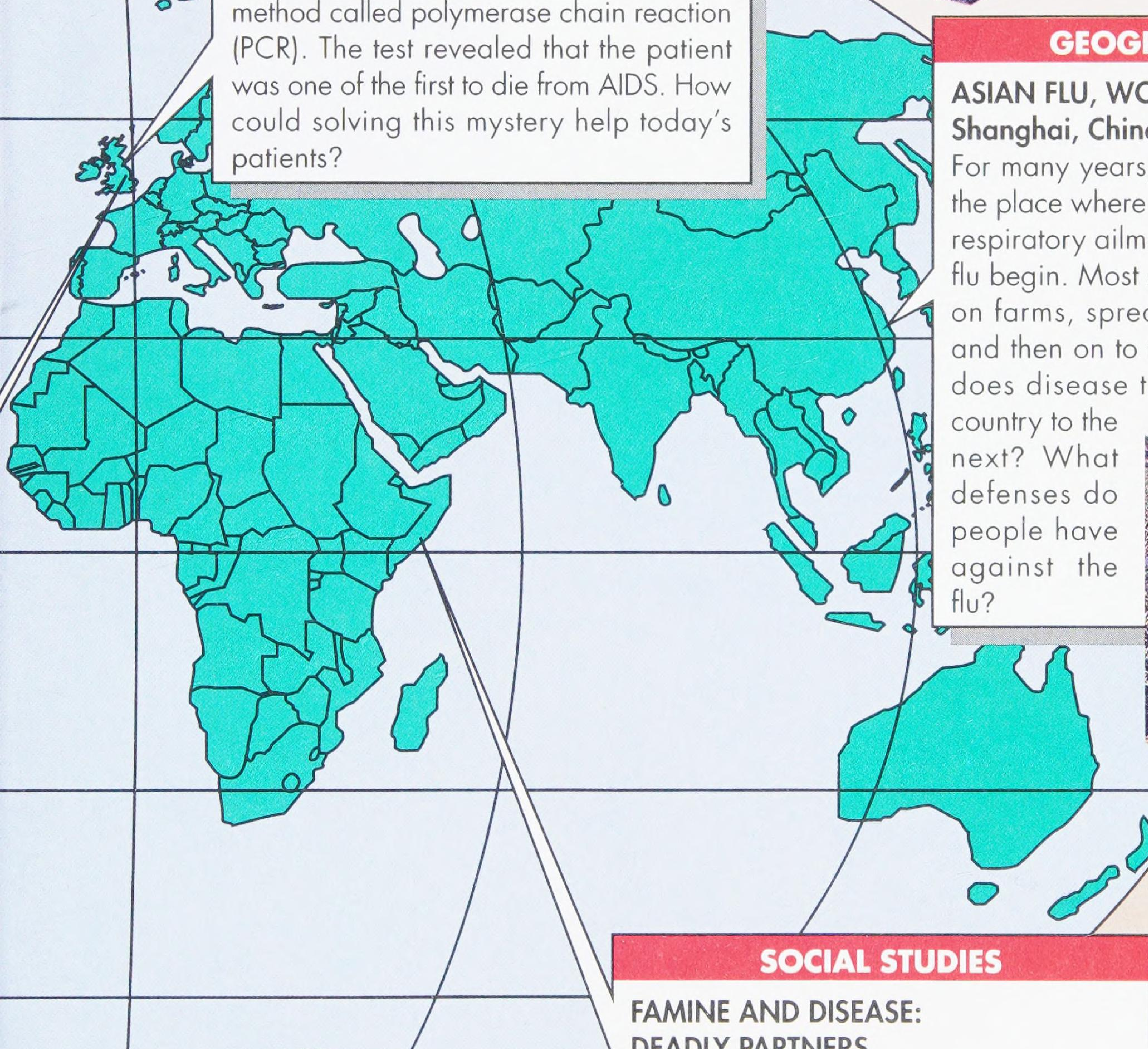
CHEMISTRY

MYSTERY EXPLAINED AFTER 30 YEARS

Manchester, England

Over thirty years ago, a young doctor, Trevor Stretton, had a patient die of a mysterious disease. Still curious, Stretton had tissue from the patient's organs tested using a new method called polymerase chain reaction (PCR). The test revealed that the patient was one of the first to die from AIDS. How could solving this mystery help today's patients?



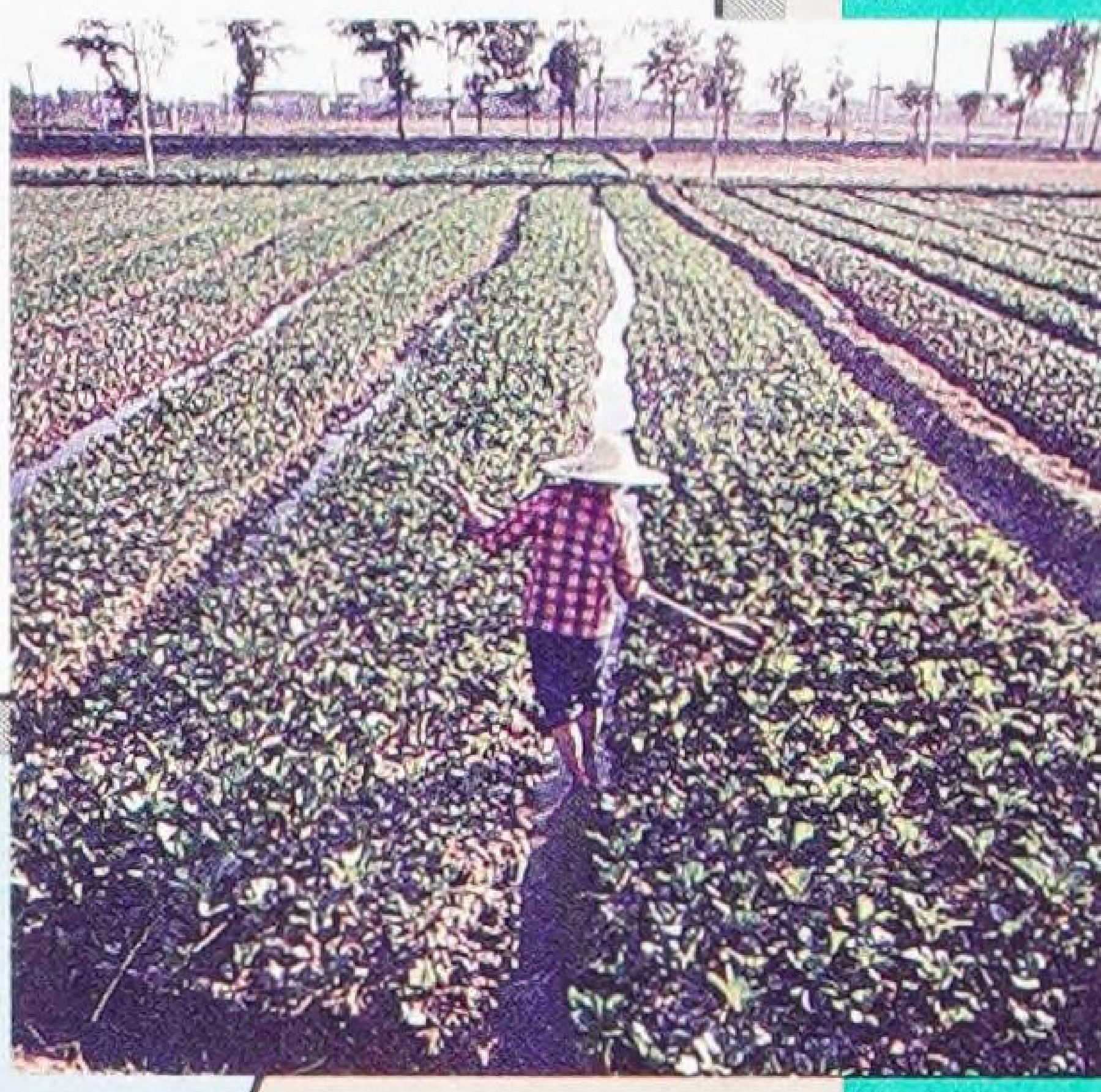


GEOGRAPHY

ASIAN FLU, WORLD PROBLEM

Shanghai, China

For many years, Asia has been the place where new strains of a respiratory ailment called Asian flu begin. Most strains originate on farms, spread to the cities, and then on to the world. How does disease travel from one country to the next? What defenses do people have against the flu?

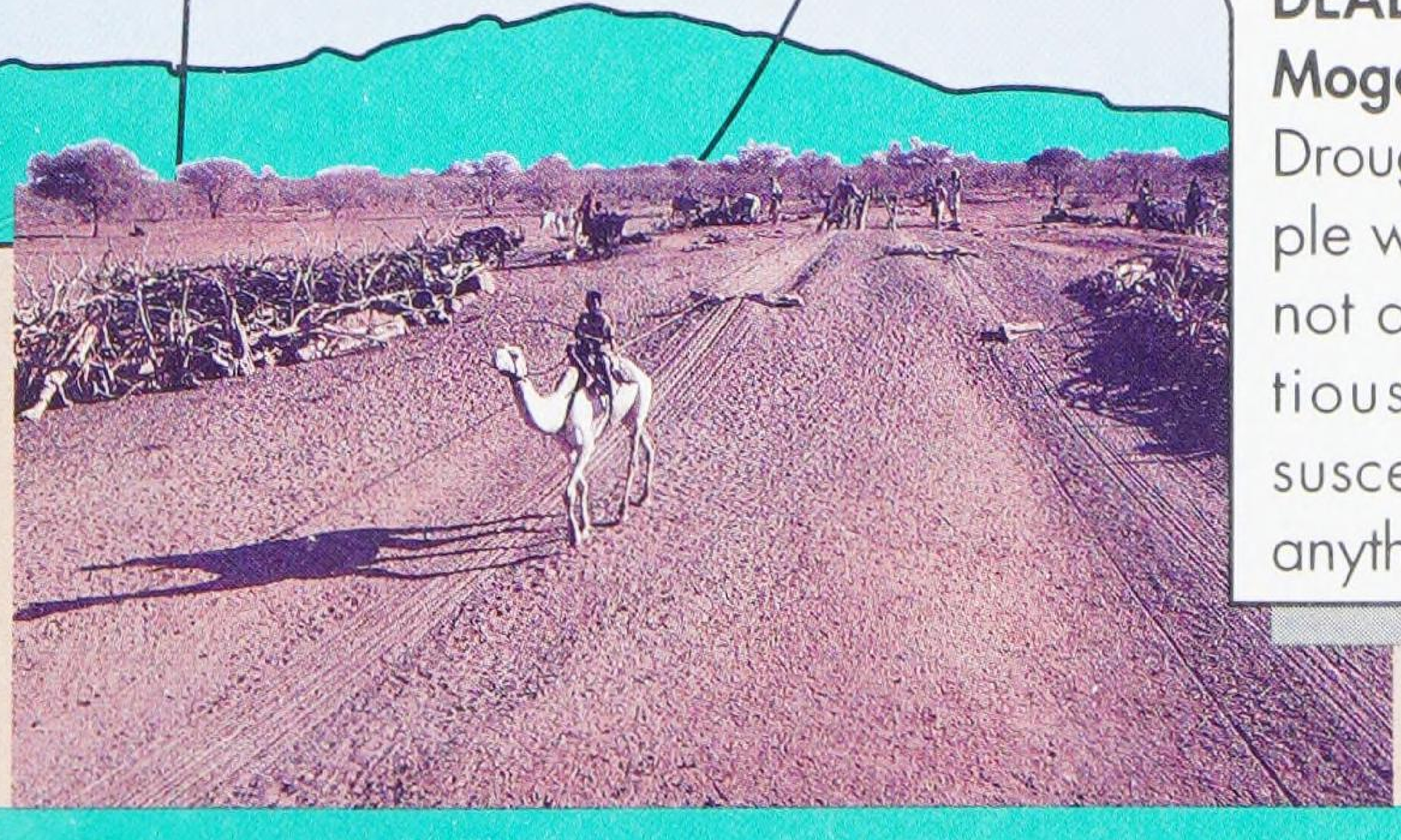


SOCIAL STUDIES

FAMINE AND DISEASE: DEADLY PARTNERS

Mogadishu, Somalia

Drought seriously affects the health of people when crops die and sufficient food is not available. Reduced sources of nutritious food cause people to be more susceptible to disease. Can science do anything to help people survive droughts?



CAREERS

MICROBIOLOGIST

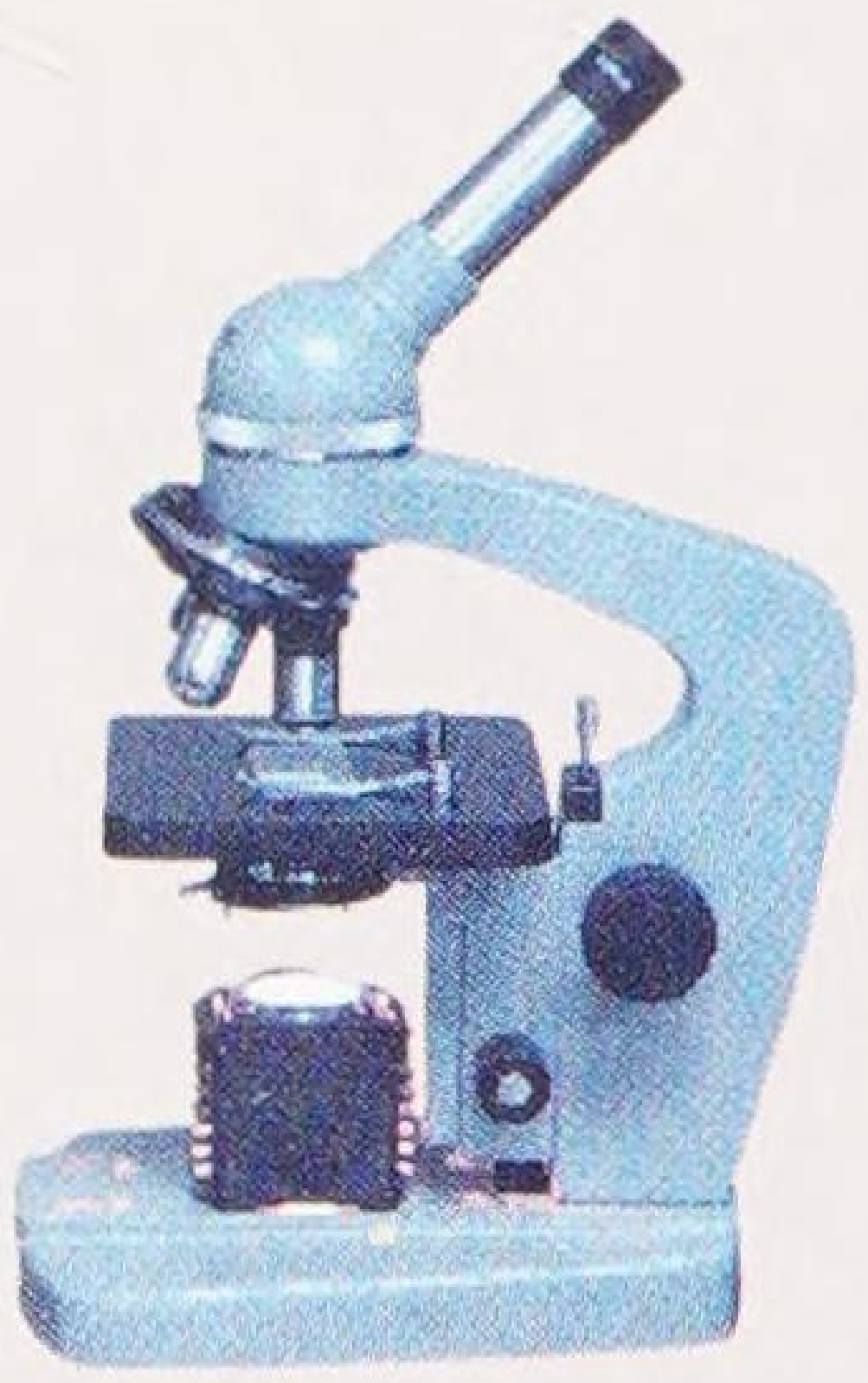
Microbiologists study the growth and characteristics of tiny living things such as bacteria, viruses, fungi, and protists. Medical microbiologists study how microorganisms cause disease and produce cures.

Microbiologists study science, math, and social studies and go on to college and graduate school before they can work.

The food industry uses microbiologists in the development of new products and in quality control. Hospitals may also employ microbiologists to track and prevent the spread of diseases within hospitals.

For Additional Information

Contact the American Society for Microbiology, Office of Educational and Professional Recognition, 1913 I Street, Washington, DC 20006.



UNIT READINGS

- Jaret, Peter. "The Disease Detectives." *National Geographic,* January 1991.
- Jordon, Robert Paul. "Somalia's Hour of Need." *National Geographic,* June 1981.
- Oliwenstein, Lori. "Medicine 1990," *Discover,* January 1991, pp. 80-83.

LICENSED PRACTICAL NURSE

Licensed practical nurses care for patients under the direction of doctors and registered nurses. They provide basic bedside care such as taking temperatures, pulse, and blood pressure. L.P.N.s work in nursing homes where, in addition to bedside care, they may also help develop care plans and supervise nursing aides.

A future L.P.N. should get as much science as possible in high school. Then he or she will go on to a state-approved training program at a trade school, community college, or hospital. Traditionally, a program for Licensed Practical Nurse can be completed in one year of full-time study.

For Additional Information

Contact the National Federation of Licensed Practical Nurses, P. O. Box 1088, Raleigh, NC 27619.

SCIENCE & LITERATURE

Medical Ethics

I will follow that system of regimen which, according to my ability and judgment, I consider for the benefit of my patients, and abstain from whatever is deleterious and mischievous.

The excerpt above is from the Hippocratic Oath, credited to Hippocrates, who is thought to have lived and practiced medicine in the 4th century B.C. Writings credited to Hippocrates have had a profound influence on the practice of medicine and were used as a framework for the training of doctors. Over the centuries, the oath as originally stated was modified many times. Both Christian and Islamic versions have existed. In 1949, the World Medical Association in Geneva, Switzerland, drew up a statement of medical ethics, called the Declaration of Geneva, which reflects many of the ideals that are thought to have been expressed in the original Hippocratic Oath. That statement follows.

I solemnly pledge myself to consecrate my life to the service of humanity;

I will give my teachers the respect and gratitude which is their due;

I will practice my profession with conscience and with dignity;

The health of my patient will be my first consideration;

I will respect the secrets which are confided in me;

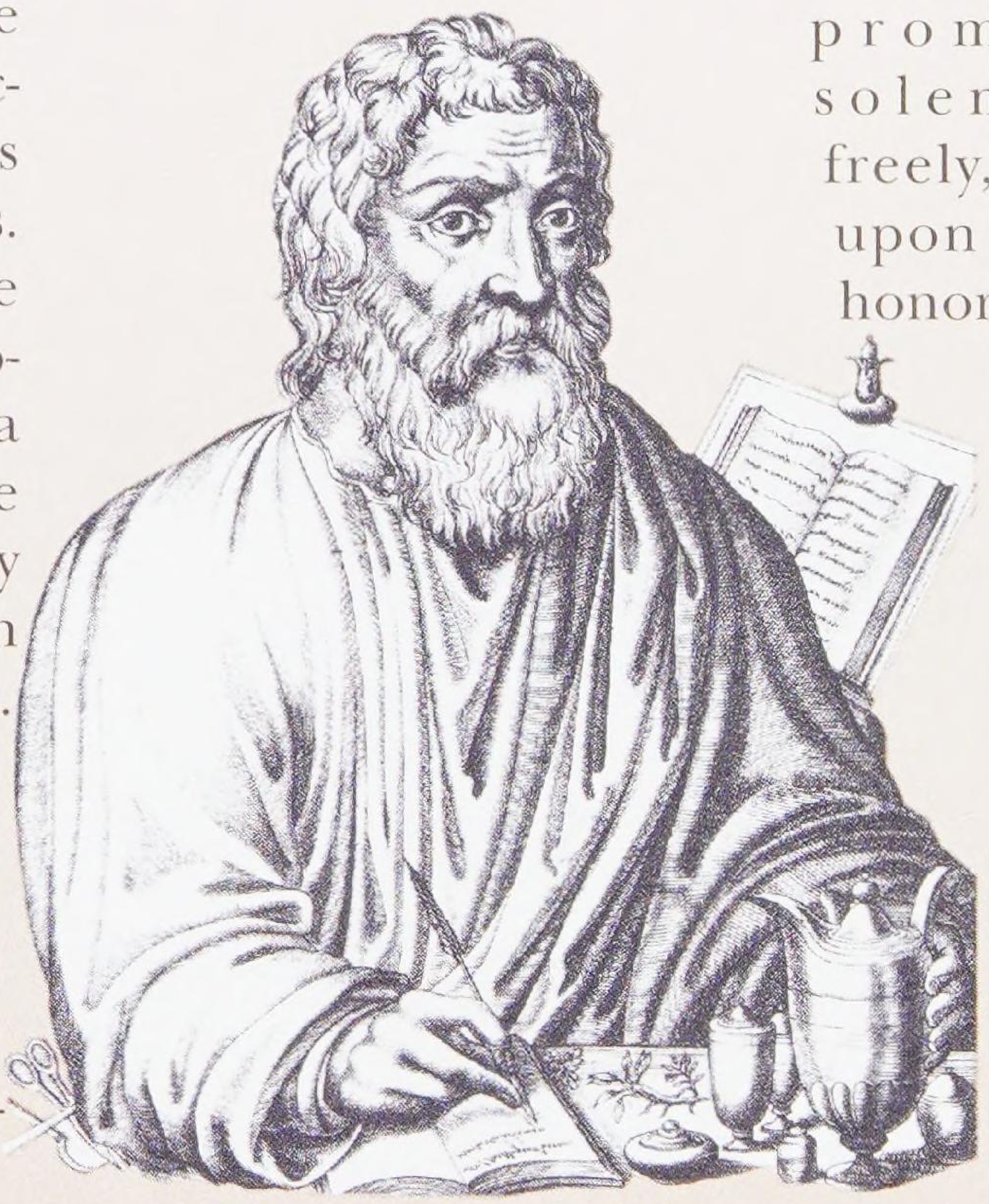
I will maintain by all the means in my power, the honor and the noble traditions of the medical profession;

My colleagues will be my brothers;

I will not let considerations of religion, nationality or race, party politics or social standing to intervene between my duty and my patient;

I will maintain the utmost respect for human life from its beginning; even under threat I will not use my medical knowledge contrary to the laws of humanity;

I make these promises solemnly, freely, and upon my honor.



In Your Own Words

- Information on the healing arts in other cultures is older than Hippocrates. Research acupuncture, moxa, and chi in Chinese medicine.

UNIT

8 ECOLOGY

What's Happening Here?

Mighty oak trees grow from acorns like these, but not all acorns become trees. As acorns ripen and fall off the tree, many become food for bears, deer, and mice. Squirrels, magpies, and jays bury acorns as winter approaches. Some acorns are attacked by acorn weevils that drill holes through the hulls to feed and lay their eggs. Once the acorn is damaged, other organisms move in. Filbert worm moths use the holes made by the weevils to lay their own eggs. When their larvae hatch, they eat their way out. Green fungi invade and decay accelerates. Maggots and springtails arrive to eat the fungi. What's in a nutshell? Life!

UNIT CONTENTS

Chapter 26 Organisms and Their Environments
Chapter 27 Biomes
Chapter 28 Resources and the Environment

CHAPTER

26 Organisms and Their Environments

Animals such as butterflies and ladybird beetles often live in large groups. They share space, food, and nesting sites. How does the number of individuals in a group affect each organism? You share your science classroom with other individuals. How much space does each person have in your science classroom?

FIND OUT!

Do this simple activity to find out how much space each person has in your classroom.

Use a meterstick to *measure* the length and width of the classroom. Multiply the length times the width to find the area in square meters. *Count* the number of individuals in your class. Divide the number of square meters in the classroom by the number of individuals. How much space does each person have? *Predict* the amount of space each person would have if your class size doubled.

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 26-1 Organisms and Their Environments
- What Is the Biosphere?
- Populations
- Communities
- Ecosystems

Section 26-2 Biotic Relationships
- Feeding Relationships
- Symbiotic Relationships in a Community
- The Transfer of Energy in a Community

Section 26-3 Abiotic Factors in the Biosphere
- Cycles of Matter
- The Water Cycle
- The Carbon-Oxygen Cycle
- The Nitrogen Cycle

Section 26-4 Science and Society Friendly Fires
- Are Forest Fires Always Bad?

Previewing Science Skills

- In the **Skill Builders,** you will observe and infer, interpret scientific illustrations, and sequence.
- In the **Activities,** you will predict, count, sample, observe, record, and use field guides.
- In the **MINI-Labs,** you will list, identify, use scientific illustrations and classify.

What's next?

Now you know that the number of individuals in a population determines the amount of space each has. In this chapter you'll learn about populations and how organisms and environments interact.

26-1 Organisms and Their Environments

New Science Words

biosphere
ecology
biotic factors
abiotic factors
population
population density
community
habitat
niche
ecosystem

Objectives

- Identify the biotic and abiotic factors in the biosphere.
- Describe the characteristics of populations.
- Compare a species' habitat and its niche within a community.

What Is the Biosphere?

Deep in the Pacific Ocean is a region where the continental plates are moving apart. As these plates pull apart, volcanic rocks and lava seep into the resulting cracks, or rifts, from beneath Earth's crust. Water near this rift zone heats up, rises, cools, and falls, creating small areas of nutrient-rich warmth in the pitch black, freezing cold waters. Few organisms are found in such waters 2.5 kilometers below the sea's surface. But in these waters the crew of a tiny submarine called *ALVIN* made a discovery that astounded scientists worldwide. An entire community of organisms was found living in darkness near the rift. The community included clams, crabs, mussels, and bacteria. With no sunlight available for photosynthesis, these bacteria produce food by chemical synthesis. About 20 of these deep ocean rift communities have now been identified in this newly discovered part of the living world.

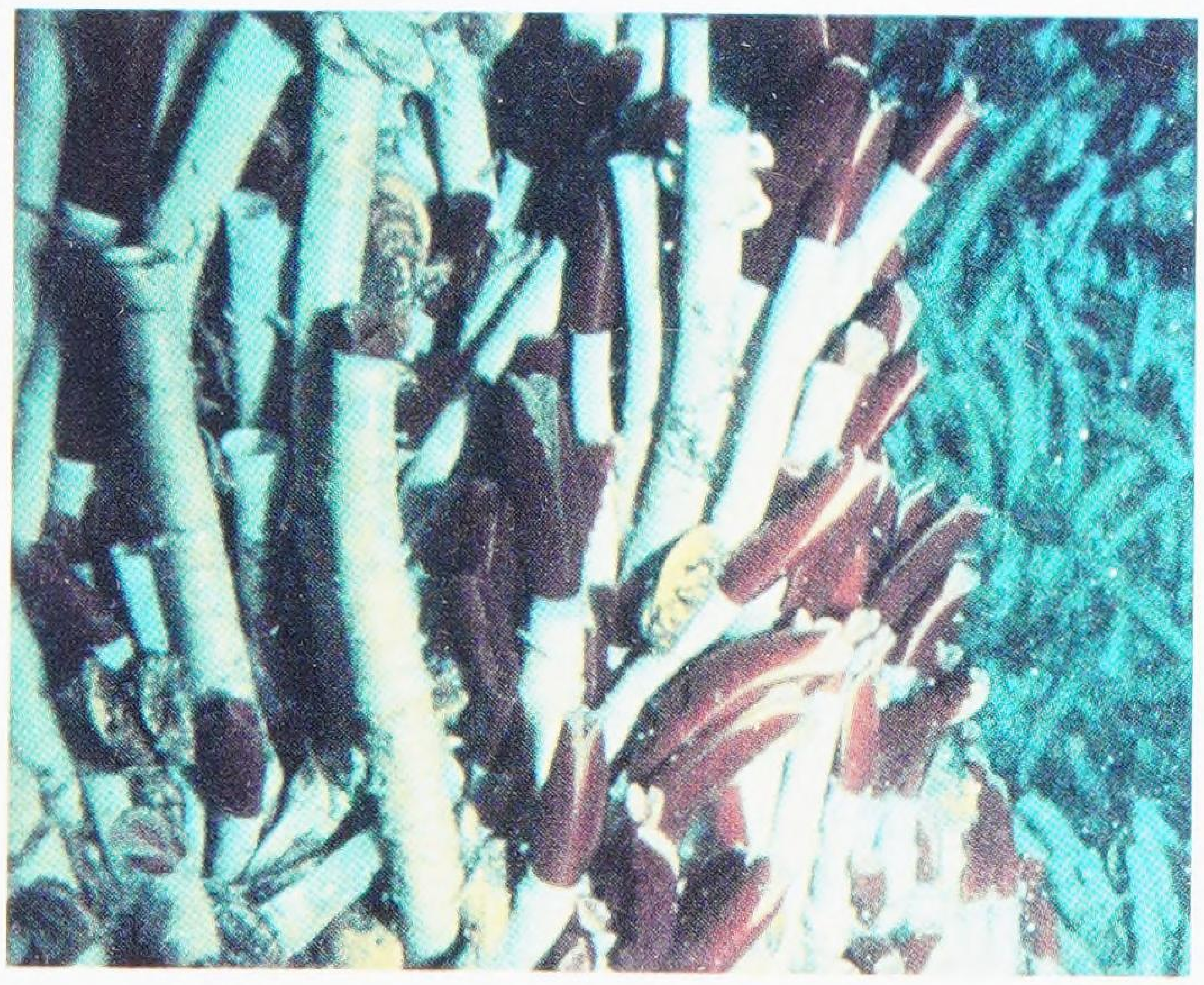


Figure 26-1. *ALVIN'S* crew photographed organisms living without light in the rift zone deep in the Pacific Ocean.

Connect to... Chemistry

The processes of photosynthesis and chemosynthesis both produce food for organisms. Define chemosynthesis. *Compare* these two processes.

Deep ocean rift communities and all the parts of Earth where life is found make up the **biosphere** (BI uh sfihr). The biosphere extends from the deepest oceans to the upper atmosphere and includes all the air, land, and water where life exists. Within the biosphere, all living things depend upon and interact with each other and with the nonliving things in their environment. The study of interactions between organisms and their environments is called **ecology** (ih KAHL uh jee). Living things such as plants and animals in the environment are called **biotic** (bi AHT ihk) **factors.** Nonliving things in the environment, such as soil, water, temperature, air, light, wind, and minerals, are **abiotic** (ay bi AHT ihk) **factors.**

Look at the pond in Figure 26-2. The abiotic factors include the pond's water, the soil at the pond bottom, and the temperatures of the air and water. The amount of light available for photosynthesis and the minerals dissolved in the water also are abiotic factors. What organisms make up the biotic factors in the pond? Monerans, protists, fungi, plants, and animals are the biotic factors.

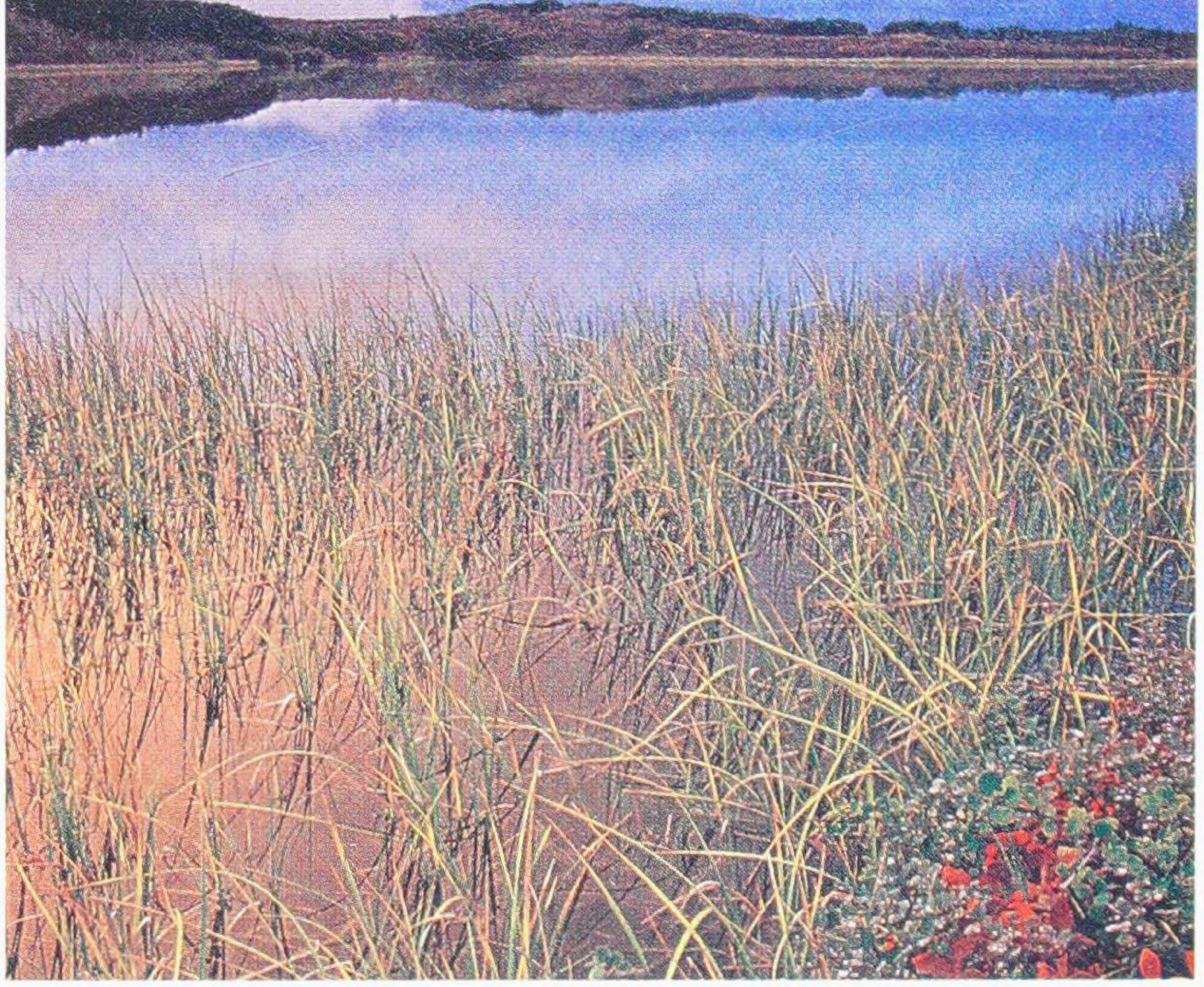


Figure 26-2. Biotic and abiotic factors work together in ecological systems like this pond.

Each species in the pond makes up a population. All of the populations in the pond make up the pond community. Together, the pond community and the abiotic factors make up an ecological system, or ecosystem. You'll learn more about populations, communities, and ecosystems in the following sections.

PROBLEM SOLVING

The Milk Carton Garden

Paulo was disappointed. He was eager to start his spring vegetable garden, but the weather forecaster predicted cold temperatures for at least another week.

Because he couldn't plant outside due to the cold temperatures, he decided to plant some bean seeds inside and transplant the seedlings when the weather warmed up.

Paulo cut the top off a 0.5-liter milk carton and filled it with nutrient-rich soil. He planted 25 seeds in the carton, placed it on a window ledge in a sunny area, and kept the soil moistened. After ten days, the bean plants had sprouted and seemed to be growing well. But, after three weeks, the plants had tall, thin stems and yellowish leaves. Several plants had withered and died. What should Paulo have done to take care of the plants?

Think Critically: Explain why the plants were healthy when they sprouted but were unhealthy after three weeks.

$1.19
Pencil Pod
Black Wax
BUSH BEAN
LONG-TIME FAVORITE
NET WT. 1.5 oz
HEAT TOLERANT
$1.19
Stringless
Green Pod
BUSH BEAN
NET WT. 1.5 oz

Populations

Have you ever gone for a walk at dusk and noticed birds lined up on a telephone wire as shown in Figure 26-4? These birds all live together in the same place at the same time; they make up a population. All the people living in your town, the flocks of geese on a pond, and the worms in the soil under a baseball diamond each represent a population. A **population** consists of organisms of one species living together in the same place at the same time.

Populations are described according to certain characteristics. The number of individuals in a given area is called **population density.** In the chapter opening activity, you found how much space each student had in your classroom. To find the population density, you must divide the area by the number of individuals in the area (density = individuals/unit area).

Another characteristic of populations is spacing. Spacing is how individuals are arranged in an area. They may be arranged evenly, like the birds on the wire, unevenly, or in random clumps. Figure 26-4 shows the types of spacing found in populations.

Size is an important characteristic of populations. The size of a population is constantly changing as individuals move into and out of a community. Populations also change when new individuals are born and when older individuals die. The total size of a population can be determined by studying these changes over time. The United States Census Bureau uses information such as this to determine the size of the human population in the United States every ten years. Figure 26-3 shows how population size changes over time.

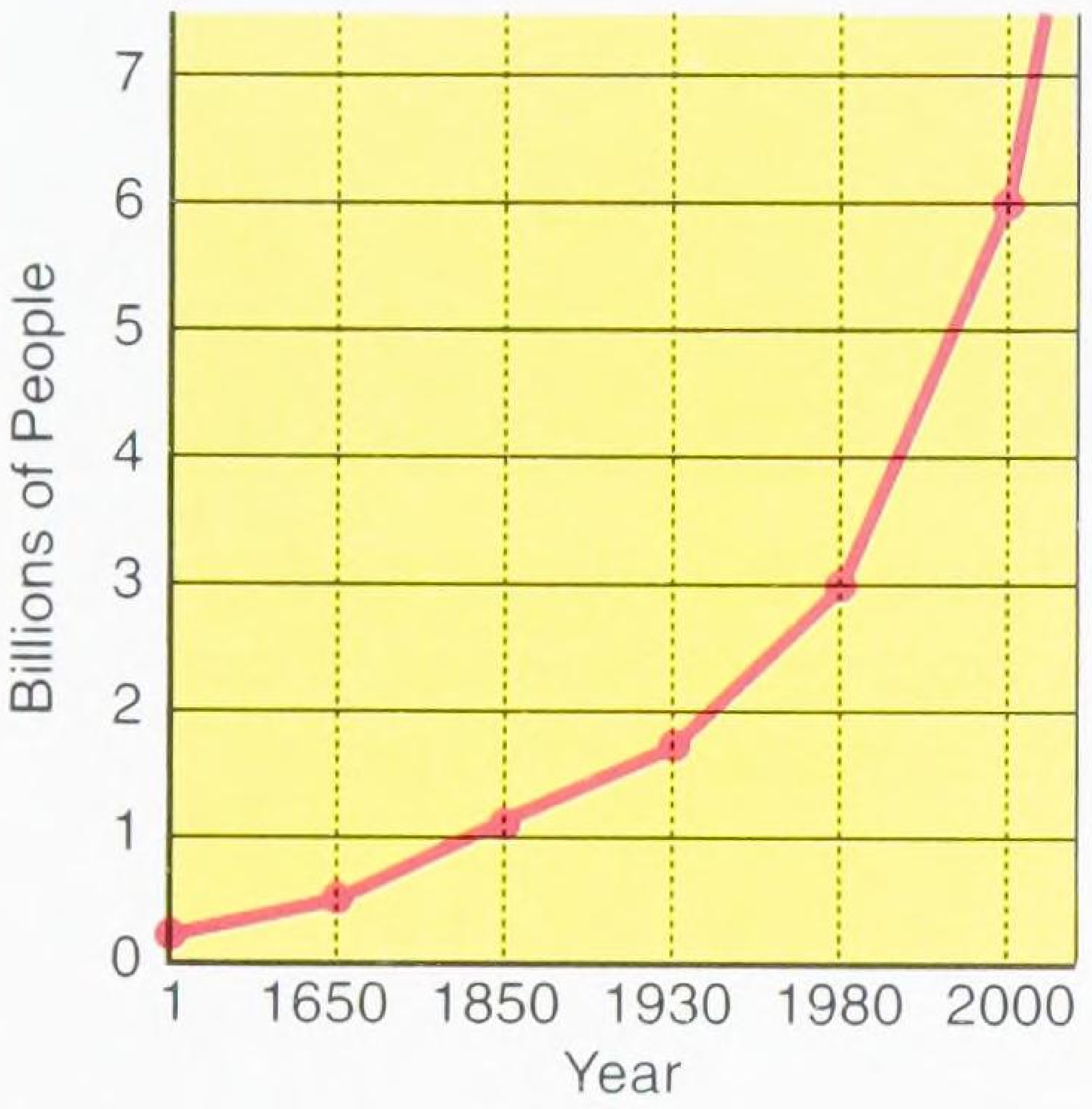


Figure 26-3. The world's population size changes over time.

Science and MATH

Calculate the population density of your city or county and compare it to that of New York City.

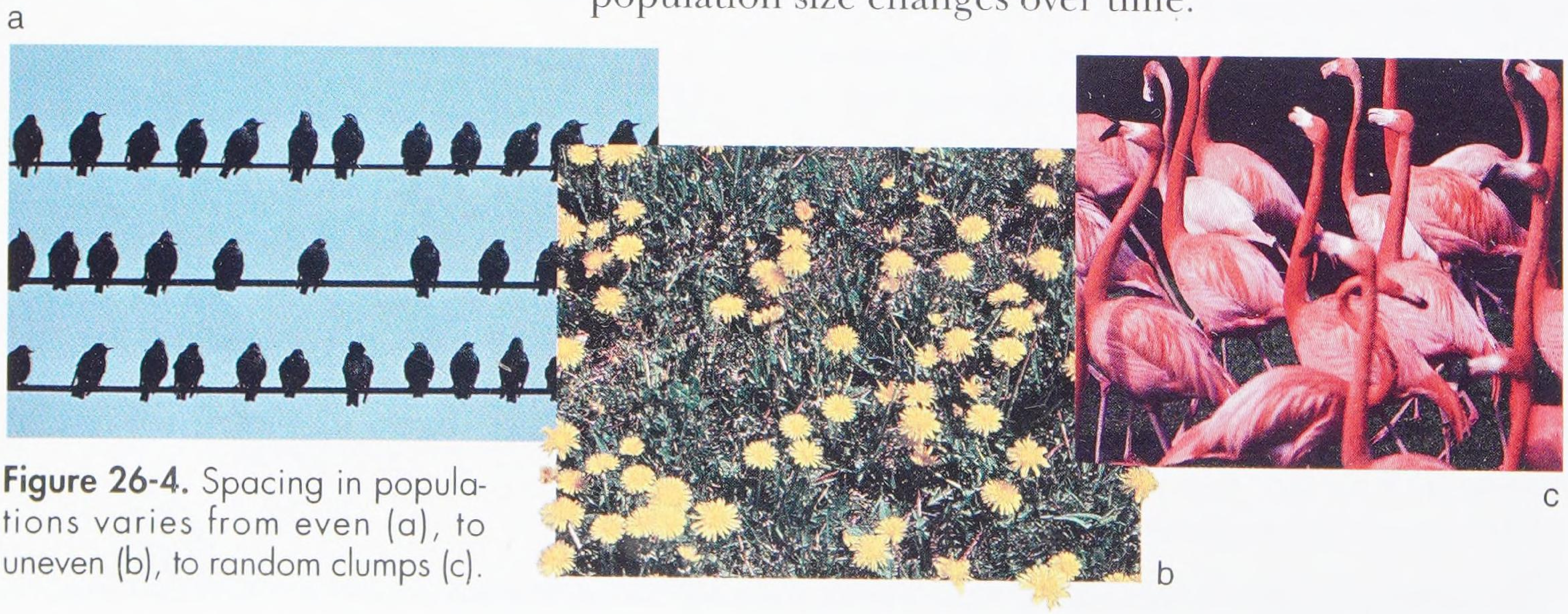


Figure 26-4. Spacing in populations varies from even (a), to uneven (b), to random clumps (c).

ACTIVITY 26-1

Counting Populations

Problem: *How can you determine the size of a population?*

Materials

- permanent marker
- clear plastic sheet

Procedure

1. *Estimate* the number of ladybird beetles below and record the number in a table like the one shown.
2. Place a clear plastic sheet over the diagram. Make a population count by placing a check mark next to each ladybird beetle. Record the actual number of beetles in the table. Next to this number, record the amount of time it took to make the count.
3. *Count* the ladybird beetle population a second time by sampling. A *sample* is made by selecting and counting only a portion of the population. Count the number of ladybird beetles in the top left square and record this number in the table.
4. Enter the total number of squares in the table. Multiply the number of ladybird beetles in the top left square by the total number of squares. Record this estimated total number in the table.
5. At the top of the table, record the amount of time it took to make the sample count.

Data and Observations

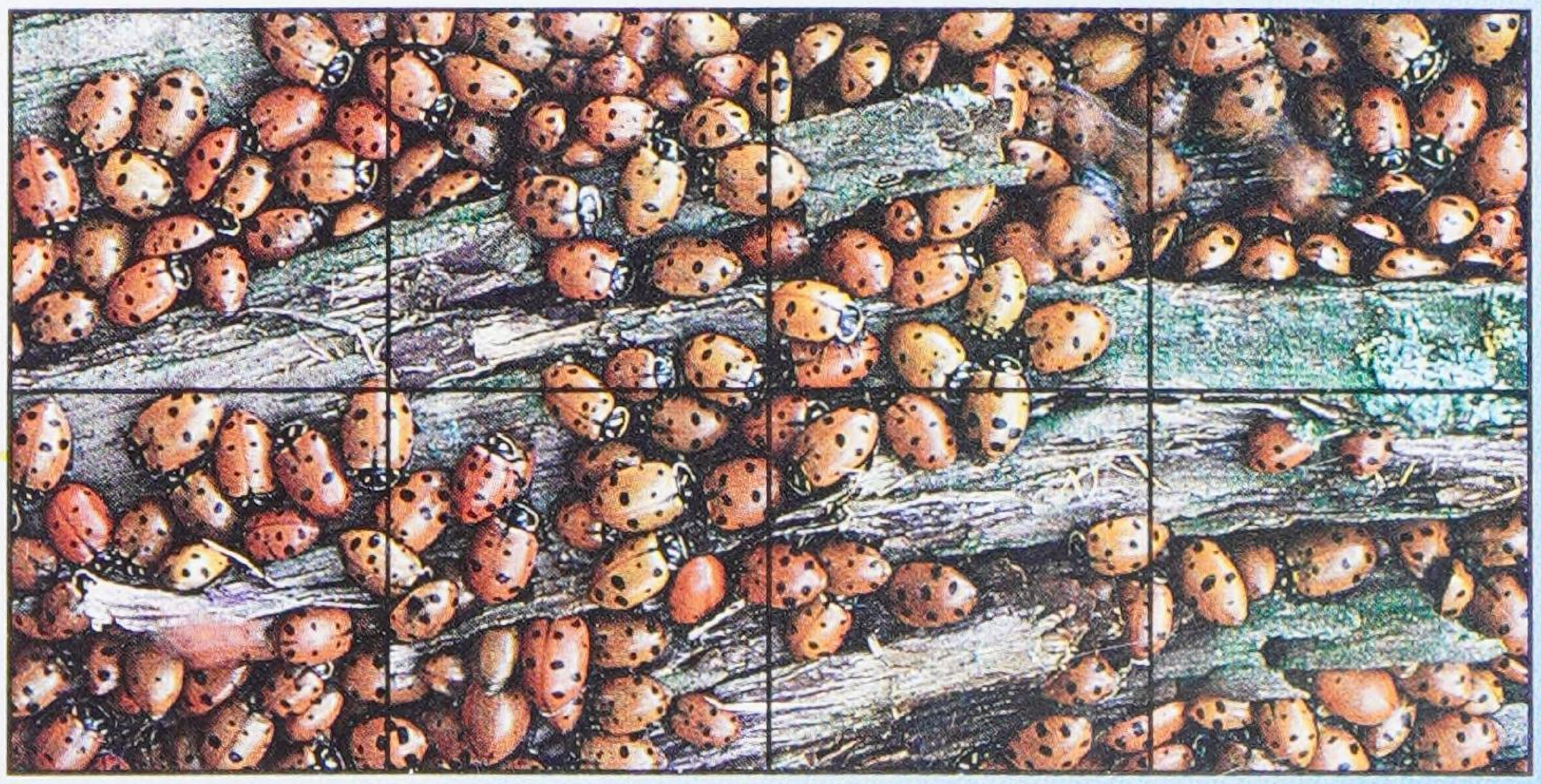
<table>
<tr><td>Predicted number</td><td colspan="4">Time</td></tr>
<tr><td></td><td colspan="4"></td></tr>
<tr><td>Number in top left square</td><td>×</td><td>Total number of squares</td><td>=</td><td>Estimated total number</td></tr>
<tr><td></td><td>×</td><td></td><td>=</td><td></td></tr>
<tr><td>Actual number</td><td colspan="4">Time</td></tr>
<tr><td></td><td colspan="4"></td></tr>
</table>

Analyze

1. How did the estimated and actual numbers of ladybird beetles *compare*?
2. How many ladybird beetles did you *estimate* were shown?
3. Which was was faster—making an actual count or sampling?

Conclude and Apply

4. *Compare* and *contrast* the methods of making an actual population count and sampling.
5. What can you *conclude* about determining the size of a population?



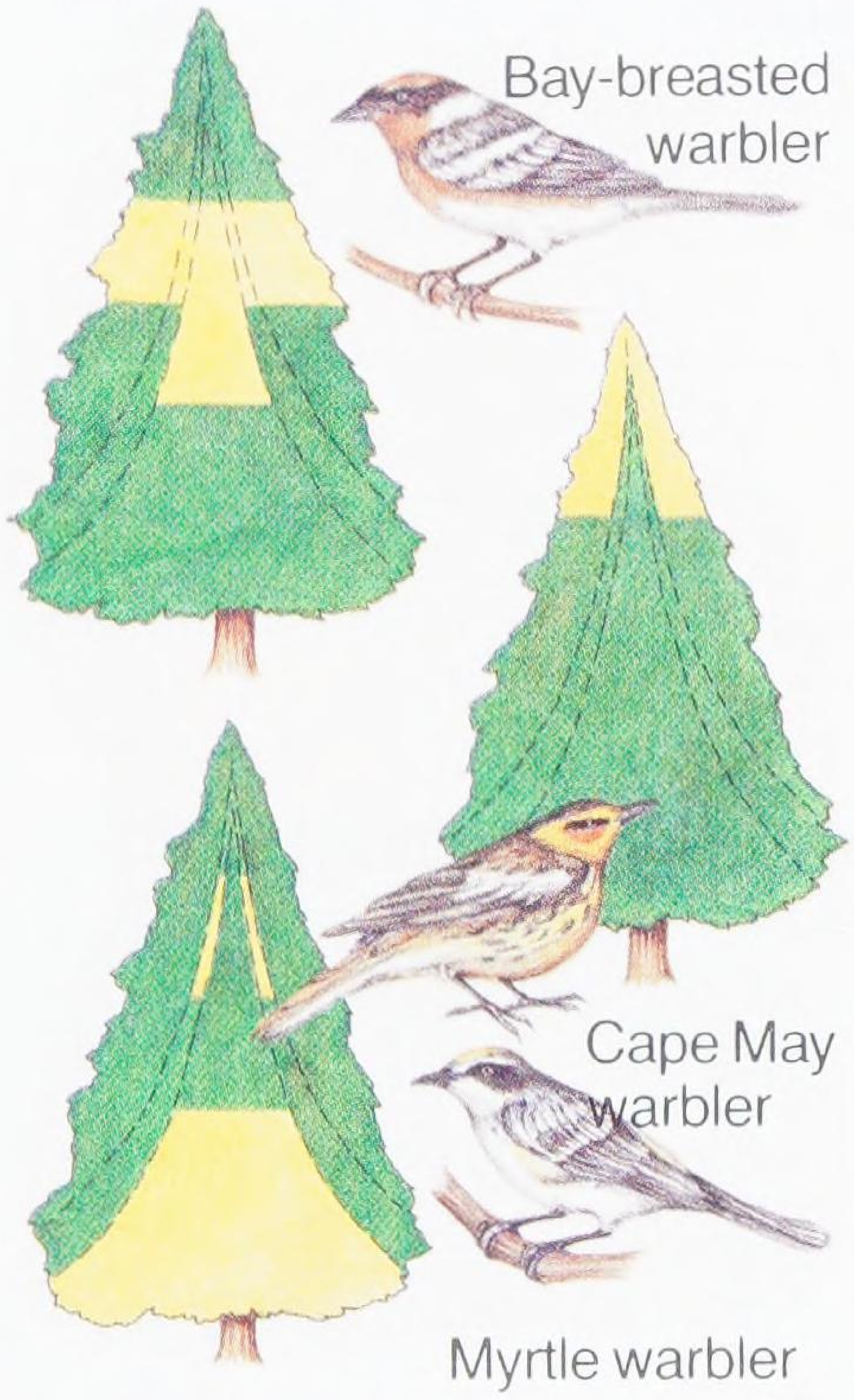
Communities

What is a community?

Hundreds of populations of organisms make up the oak-hickory forest community shown in Figure 26-6. A **community** is made up of all the populations of different species that live in the same place at the same time. In a community, a few species are usually more abundant than others. These species are called dominant species.

The oak and hickory trees are the dominant species in the community shown in Figure 26-6. When their leaves open in the spring, they create so much shade that plants underneath the trees cannot grow. In the autumn, their leaves fall and provide food for bacteria, fungi, and worms on the forest floor. Many other organisms eat the acorns and nuts produced by the trees. The tree trunks and branches are homes for insects, birds, squirrels, lichens, and other organisms. All the populations in this forest community depend on one another for survival.

Figure 26-5. Although all three warblers feed in the same spruce tree, they occupy very different niches.



The place where an organism lives in a community is its **habitat.** Squirrels live in the trees in the forest. You would probably find crayfish, minnows, and other organisms living in the streams in the forest. Water is the habitat of these organisms. What is your habitat?

What is a niche?

No two species have exactly the same needs or role in a community. The role of a species within a community is its **niche** (NIHCH). What a species eats, how it gets its food, and how it interacts with other organisms are all part of its niche. You may have seen many birds at a bird feeder in the park. Sparrows, doves, and cardinals all feed on birdseed—but not necessarily the same kinds of seeds. Two different species can occupy the same habitat, but they usually cannot occupy the same niche. Figure 26-5 shows how three bird species can live in one tree and still occupy very different niches.

Figure 26-6. In an oak-hickory forest, oaks and hickories are the dominant species.

To compare a community, a habitat, and a niche, we can look at the floor of the oak-hickory forest community. When a termite lives on and eats the wood of a fallen tree, the tree is the termite's habitat. Breaking down the parts of the dead tree is the termite's niche within the community.

Ecosystems

An oak-hickory forest community is one type of ecosystem. A coral reef such as the one shown in Figure 26-7 is another type of ecosystem. A coral reef is composed of corals, sponges, sea stars, sea anemones, clown fish, trigger fish, groupers, algae, clams, mussels, oysters, and many other organisms. The ocean water, with its currents, temperature, and salinity, affects all of the organisms living on or near the coral reef. The amount of sunlight reaching the reef helps determine how much food the plantlike protists produce, and it affects those organisms that eat the protists. Together, these biotic and abiotic factors interact and function as an ecosystem. An **ecosystem** is a community interacting with the abiotic parts of its environment. Ecosystems may be as small as the acorn you studied in the unit opener, or as large as the Pacific Ocean. There are some very large natural ecosystems, such as forests, on Earth. You will learn about these ecosystems in Chapter 27.

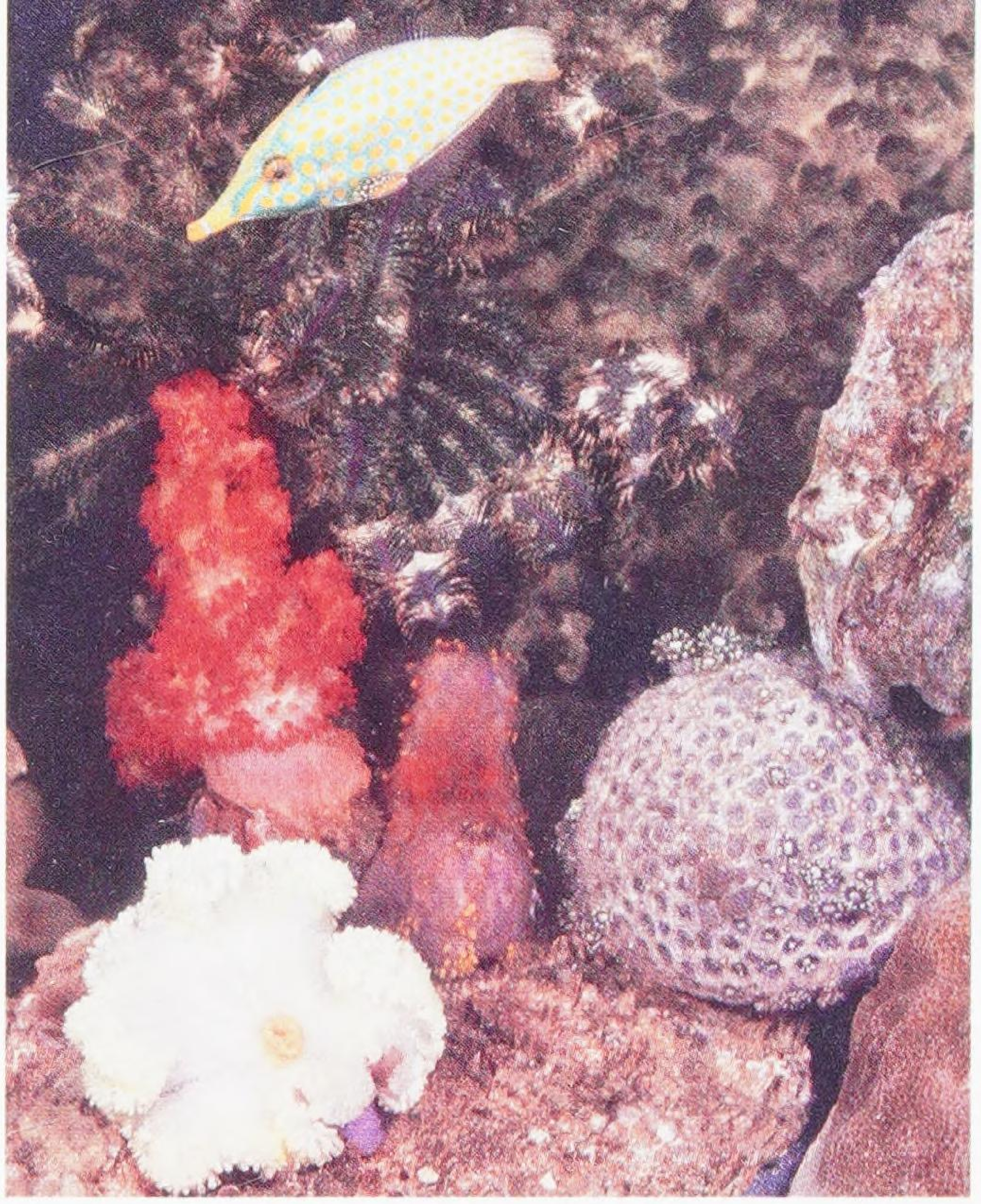


Figure 26-7. All of the organisms living on or near this coral reef are part of the community that interacts with the ocean water to form this ecosystem.

What is an ecosystem?

SECTION REVIEW

1. Name five biotic and five abiotic factors in the biosphere.
2. Describe the difference between a population and a community.
3. How are niches and habitats different ?
4. **Apply:** Ecosystems such as coral reefs are in a delicate balance. Hypothesize what would happen to that balance if one abiotic factor such as amount of sunlight suddenly changed.
5. **Connect to Earth Science:** Find out how the eruption of Mt. St. Helen in Washington state in 1980 affected the population densities of area organisms.

MINI-Lab

What organisms are found in an ecosystem?

Choosing an ecosystem you are familiar with, such as a stream, garden plot, or empty lot, *identify* the organisms found there. Make a list of all the populations you can see in the ecosystem. *Infer* the niche of each species in the community.

Observing and Inferring

Skill Builder

Each person lives in a population as part of a community. Describe your population, community, habitat, and niche. (HINT: You may belong to more than one of each!) If you need help, refer to Observing and Inferring in the **Skill Handbook** on page 682.

26-2 Biotic Relationships

New Science Words

competition
camouflage
mimicry
food chain
food web
energy pyramid

Connect to... Earth Science

When soils are damaged by overgrazing in areas that receive little rain, a desert can form. Called desertification, desert formation is currently happening in some areas of Africa, China, and the United States. Find out more about desertification, how quickly it occurs, and the problems it causes.

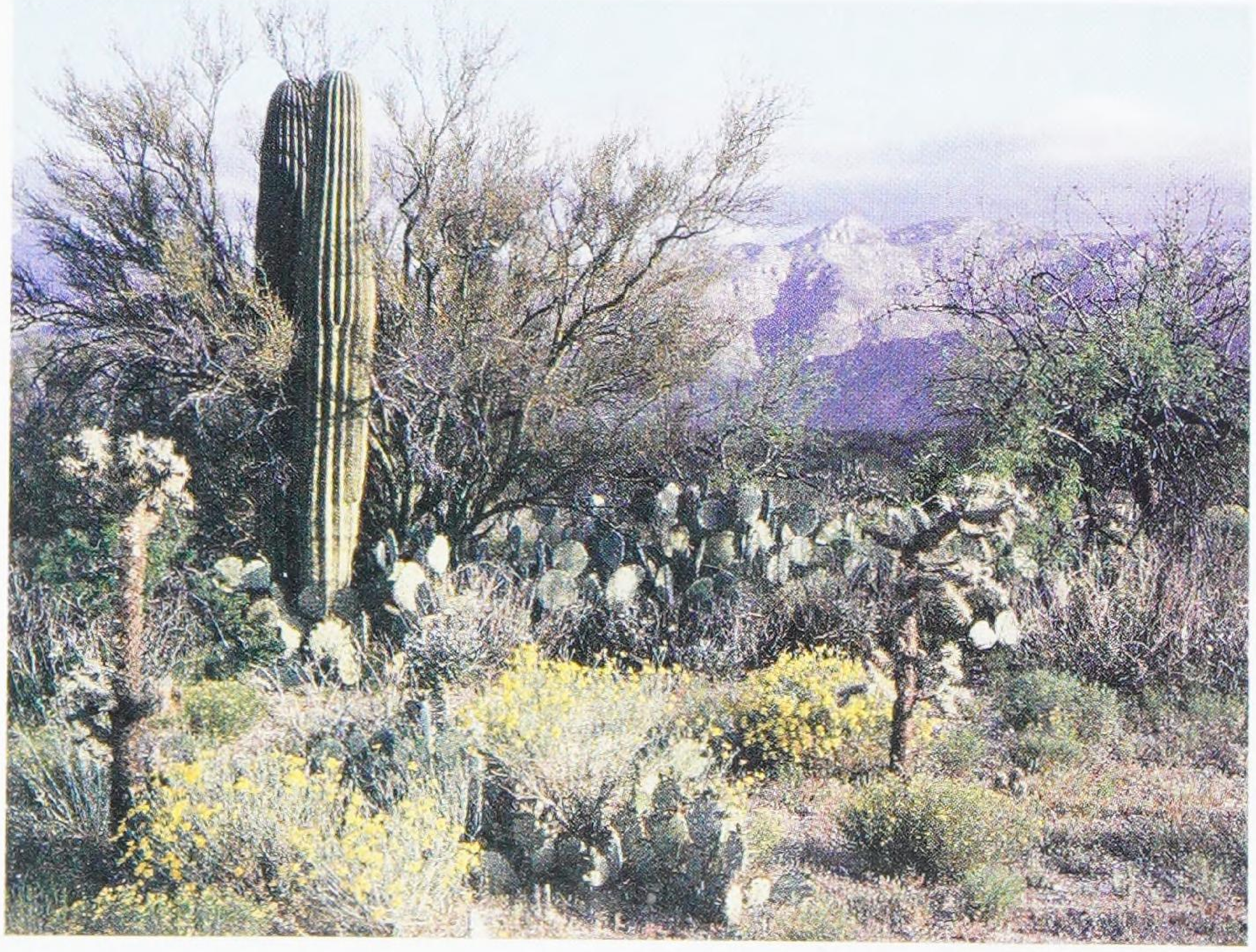
Objectives

- Identify kinds of relationships organisms have with each other.
- Describe food chains and food webs in a community.
- Explain how energy is transferred through a community.

Feeding Relationships

What are the biotic factors in a desert such as the one shown in Figure 26-8? Many desert animals burrow underground for protection from the sun, only venturing out after dark. The plants are cacti and other plants with leaves modified into needles to conserve water. In the desert ecosystem, the amounts of food, water, and nutrients are limited, yet the amounts of sunlight and living space are not. Many desert organisms have adapted to life under these conditions. Birds nest in cacti, whereas rodents burrow in the sand. Snakes and lizards, turtles, and many kinds of insects can be found in deserts. All of these organisms have relationships with one another. The relationships among living things are biotic relationships. Many biotic relationships are feeding relationships. These relationships include competition for resources and predator-prey relationships.

Figure 26-8. Desert organisms compete with one another for food, water, and living space.



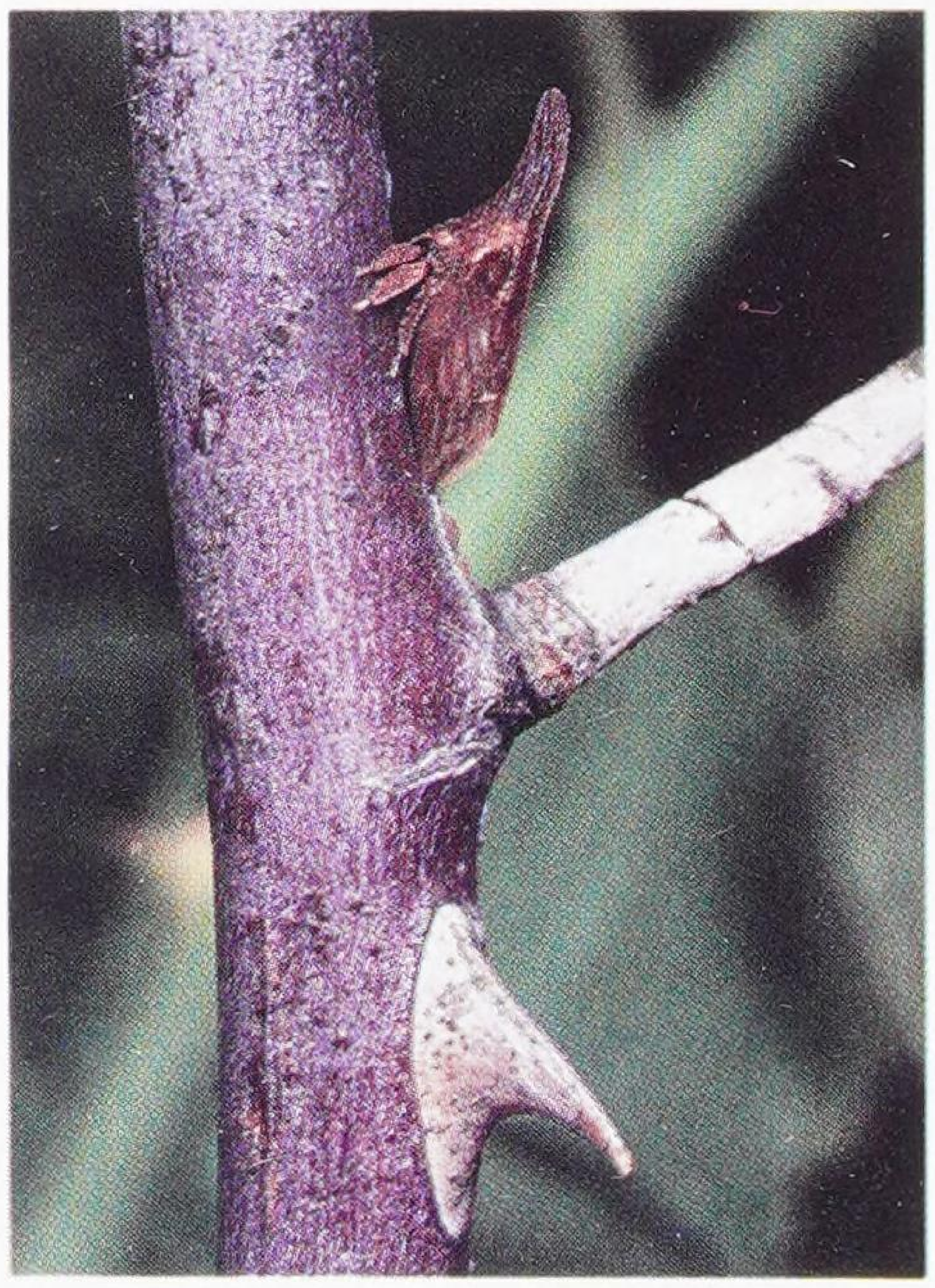
In the desert and in every other ecosystem, organisms compete for the same food, water, living space, and other resources. **Competition** is the contest among organisms to obtain all they need to survive. Competition determines the size and location of populations, and can occur between members of the same species. Members of one species often compete for nesting sites, mates, or feeding spots. Two robins will fight over one worm in the spring! If the competition is too strong, individuals may move into less populated areas.

Another kind of competition takes place between two different species. Both the owl and the fox catch and eat mice. Suppose half of the mouse population in a field suddenly died from a disease. What would happen to the owl and the fox? As long as there is a large mouse population, the owl and the fox can live in the same community. But they become competitors for food when the mouse population is reduced. In this case, the owl and the fox become competitors because they occupy the same niche—consumer of mice as food. Two organisms cannot occupy the same niche for long because one will eventually push the other out of that niche. In our example, the owl and the fox both feed on a wide variety of food organisms, so a smaller mouse population probably won't result in death for either. However, the owl and the fox will continue to compete for the remaining food sources in the community.

One important feeding relationship found in communities is the predator-prey relationship. In the oak-hickory forest community, owls and foxes are the predators, and mice are the prey. Animals that are prey can avoid being eaten by hiding, escaping, or defending themselves against predators. **Camouflage** is an adaptation that allows an animal to hide by blending into its surroundings. Insects such as the thorn bug in Figure 26-9 often can't be seen until they move.

Another defense against predators is mimicry. In **mimicry,** an animal copies the appearance or behavior of another organism.

Figure 26-9. Insects such as thorn bugs, leaf bugs, and stick insects resemble real thorns, leaves, and sticks.



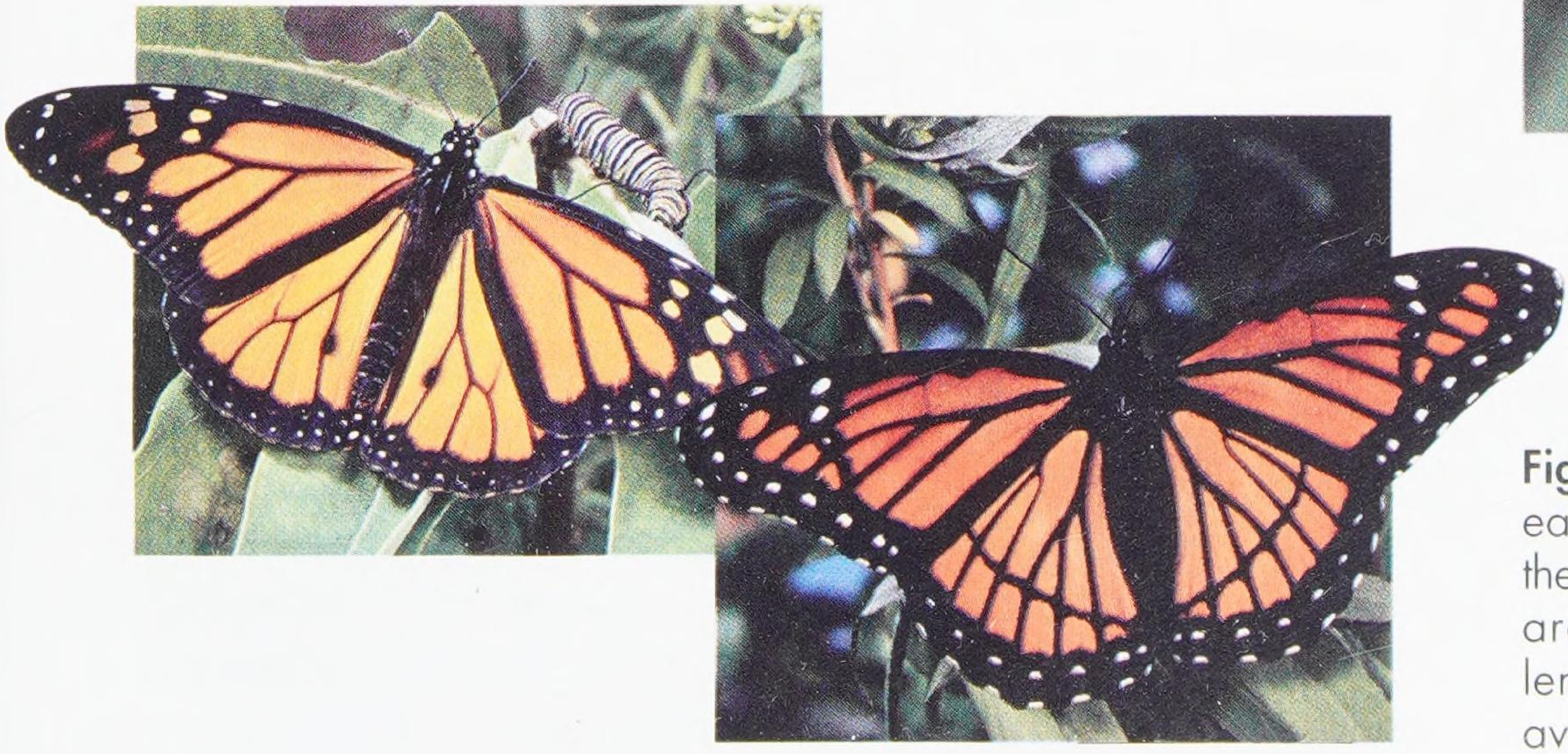


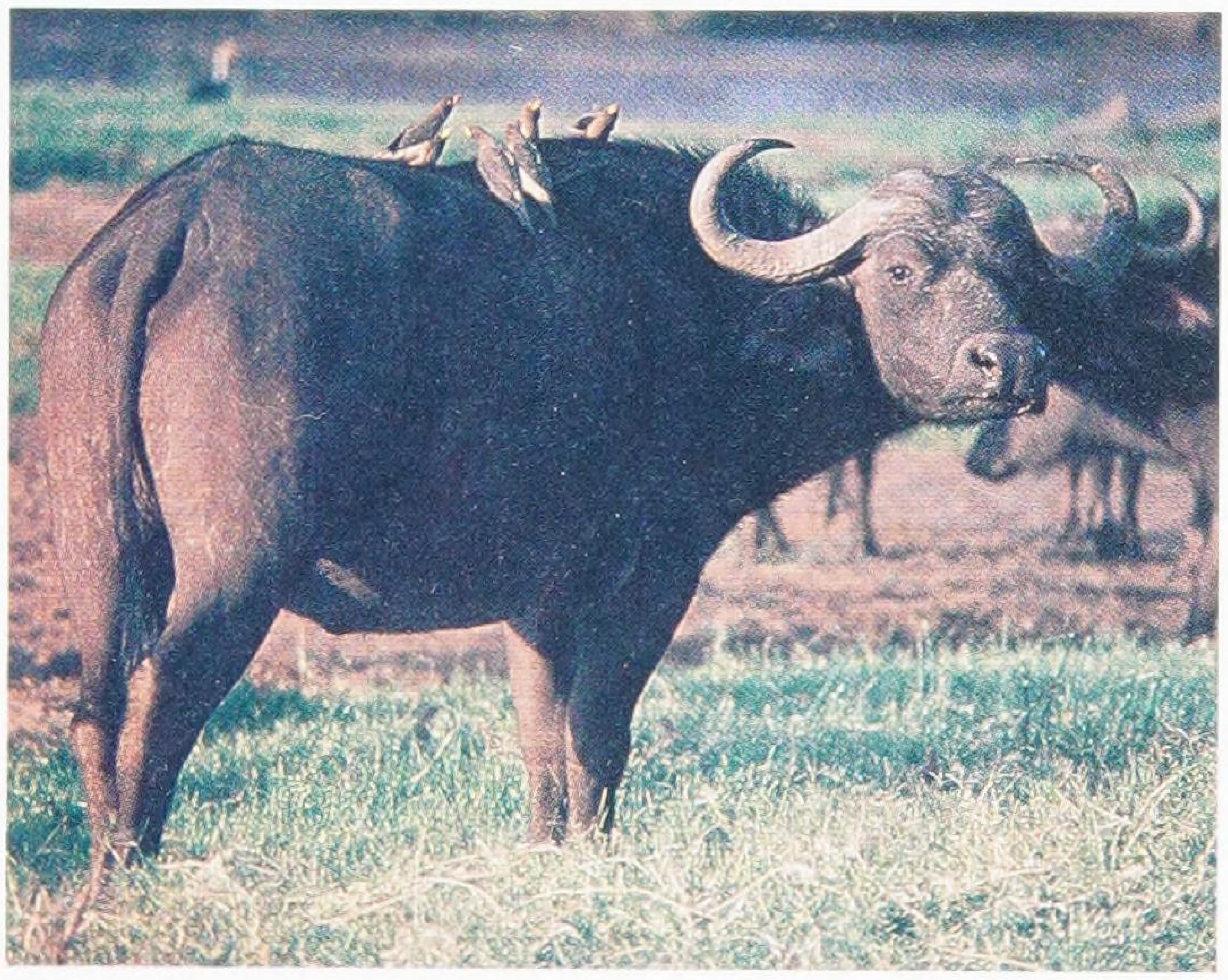
Figure 26-10. Birds learn not to eat monarch butterflies because they are bad-tasting. Viceroys (left) are protected by their resemblence to monarchs (right). Birds avoid viceroys, too.

Symbiotic Relationships in a Community

What is symbiosis?

In Figure 26-11, a bird called the oxpecker is eating insects that feed on the water buffalo. When two or more species live together, their relationship is called symbiosis. Symbiotic relationships provide food, shelter, support, or transportation for one or both organisms. Mutualism and parasitism are two types of symbiotic relationships.

Figure 26-11. The oxpecker and the water buffalo have a symbiotic relationship.



Mutualism is a symbiotic relationship in which two organisms live together and both benefit. The water buffalo and the oxpecker both benefit from their mutualistic relationship.

Parasitism is a relationship in which one organism, the parasite, is helped while the other organism, the host, is harmed. The parasite usually lives on or in the host and absorbs nutrients from the body fluids of the host. Tapeworms live as parasites in the intestines of mammals. Mistletoe is a plant that lives as a parasite on trees.

The Transfer of Energy in a Community

Many of the interactions that you have just studied are feeding relationships. Energy in food is transferred through a community by a **food chain.** In the oak-hickory forest, the trees and other producers change the energy of sunlight into chemical energy that is stored in plant leaves, stems, roots, and seeds. Consumers living in the forest community feed on these plant parts. Other consumers, such as predators, feed on these plant consumers. Decomposers break down waste materials and dead plants and animals to get energy. Food chains are a way to describe how the energy in food moves through the biotic community.

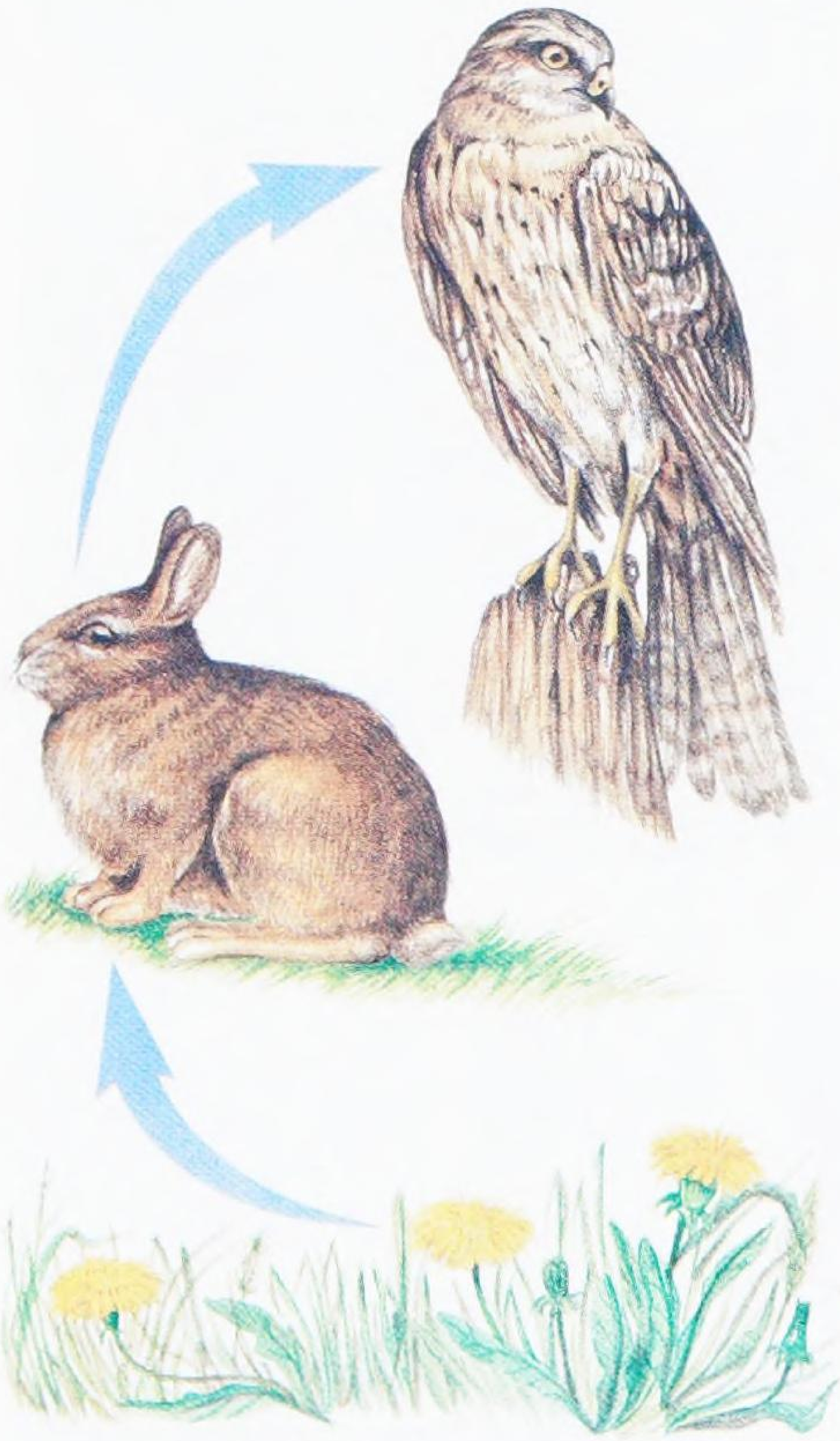


Figure 26-12. A simple food chain includes a producer, a herbivore, and a carnivore.

The simple food chain in Figure 26-12 includes the plants, the rabbit, and the hawk.

There are many food chains within a community. A consumer often feeds in a variety of food chains. Hawks, foxes, and owls all are predators that eat mice and rabbits. Mice and birds eat grains and seeds, whereas rabbits and deer both eat grass. All of these organisms feed in several food chains that overlap. A series of overlapping food chains is called a **food web.** The organisms in a food web eat or are eaten by many organisms.

Producers are the first link in any food chain. The producers provide food for themselves and the whole community. Grass, hay, and oats are examples of producers. Producers are the organisms that convert sunlight, carbon dioxide, and water into sugar and oxygen during photosynthesis. Plant-eating consumers, the herbivores, eat green plants and change some of the food stored in plants to the energy they need for life activities. Grasshoppers are herbivores that eat grass seeds. Herbivores, in turn, are eaten by meat-eating consumers, the carnivores. Woodpeckers eat grasshoppers. Some carnivores are then eaten by other carnivores. Woodpeckers, for example, are eaten by hawks. In some food webs, consumers eat both plants and animals. Consumers that eat both plants and animals are omnivores. Humans, bears, and raccoons are omnivores.

The flow of energy from grass seeds to hawks can be shown in a diagram called an **energy pyramid,** as shown

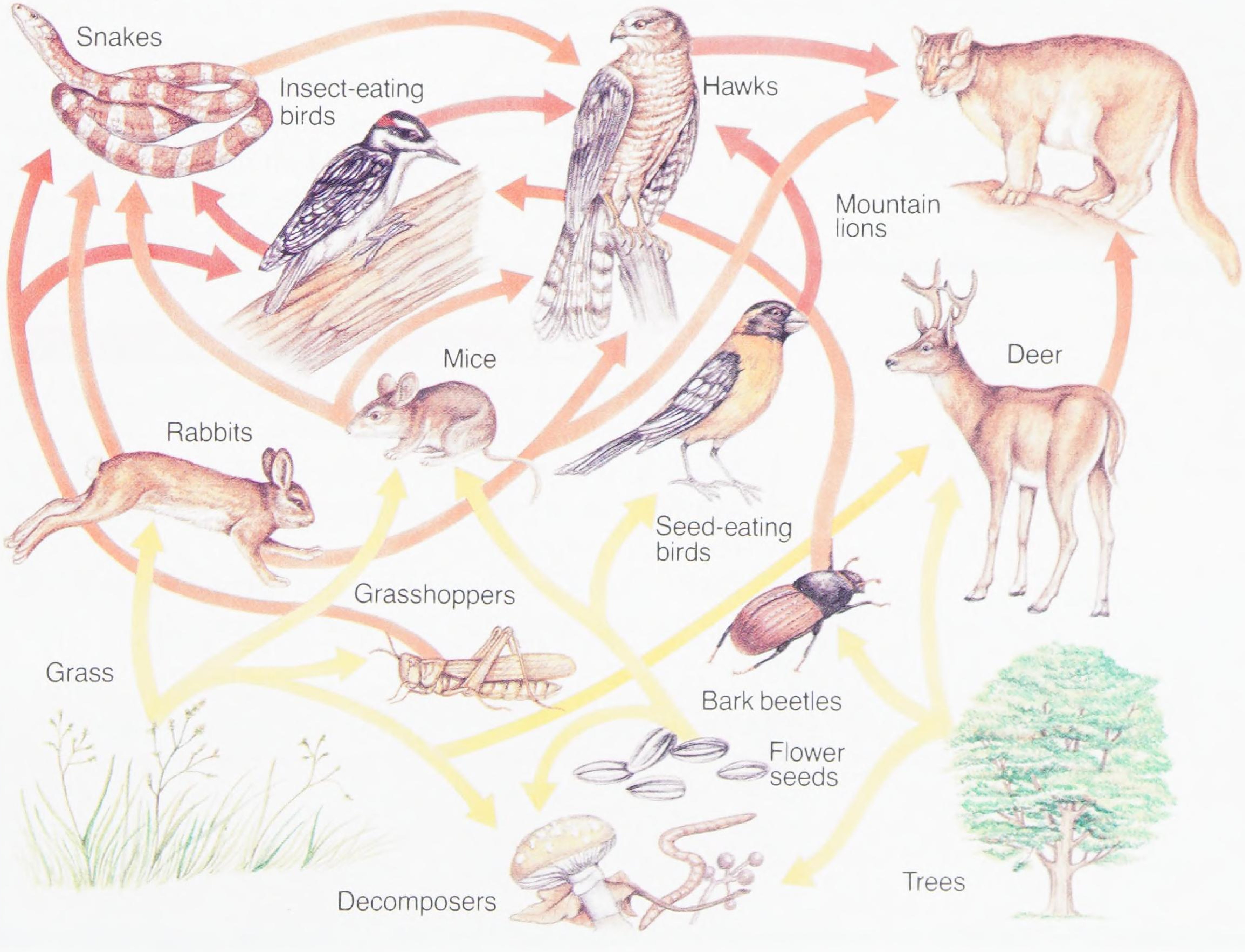
What is a food web?

MINI-Lab

What are the requirements of ecosystems?

In your Journal, *classify* the organisms in Figure 26-13, as producers, consumers, herbivores, carnivores, or omnivores. Next, list all the abiotic factors you can think of that are needed for these organisms to survive.

Figure 26-13. A Food Web


Snakes
Insect-eating birds
Hawks
Mountain lions
Mice
Deer
Rabbits
Seed-eating birds
Grasshoppers
Grass
Bark beetles
Flower seeds
Trees
Decomposers

What is an energy pyramid?

in Figure 26-14. Notice that there are many more producers than herbivores, and many more herbivores than carnivores. Why do you think this is so? Less energy is available at each level of the pyramid as you move toward the top. Even though grasshoppers eat a lot of grass seed, they can't use all of the energy stored in grass seeds. In fact, only about ten percent of the energy in grass seed is available to the grasshopper. Only ten percent of the energy stored in the grasshopper is available to the woodpecker, and so on. The animals at the top of the energy pyramid depend on very large populations of producers and herbivores to stay alive.

Energy pyramids are one way to show the relationships of organisms in communities. A pyramid of numbers shows how many individuals an ecosystem can support. In the example shown in Figure 26-14, a pyramid of numbers would include 175 grass seeds, 40 grasshoppers, 5 woodpeckers, and 1 hawk. Pyramids of numbers may look different from energy pyramids. One tree may support thousands of insects. What would a pyramid of numbers look like if it included one tree and one thousand insects?

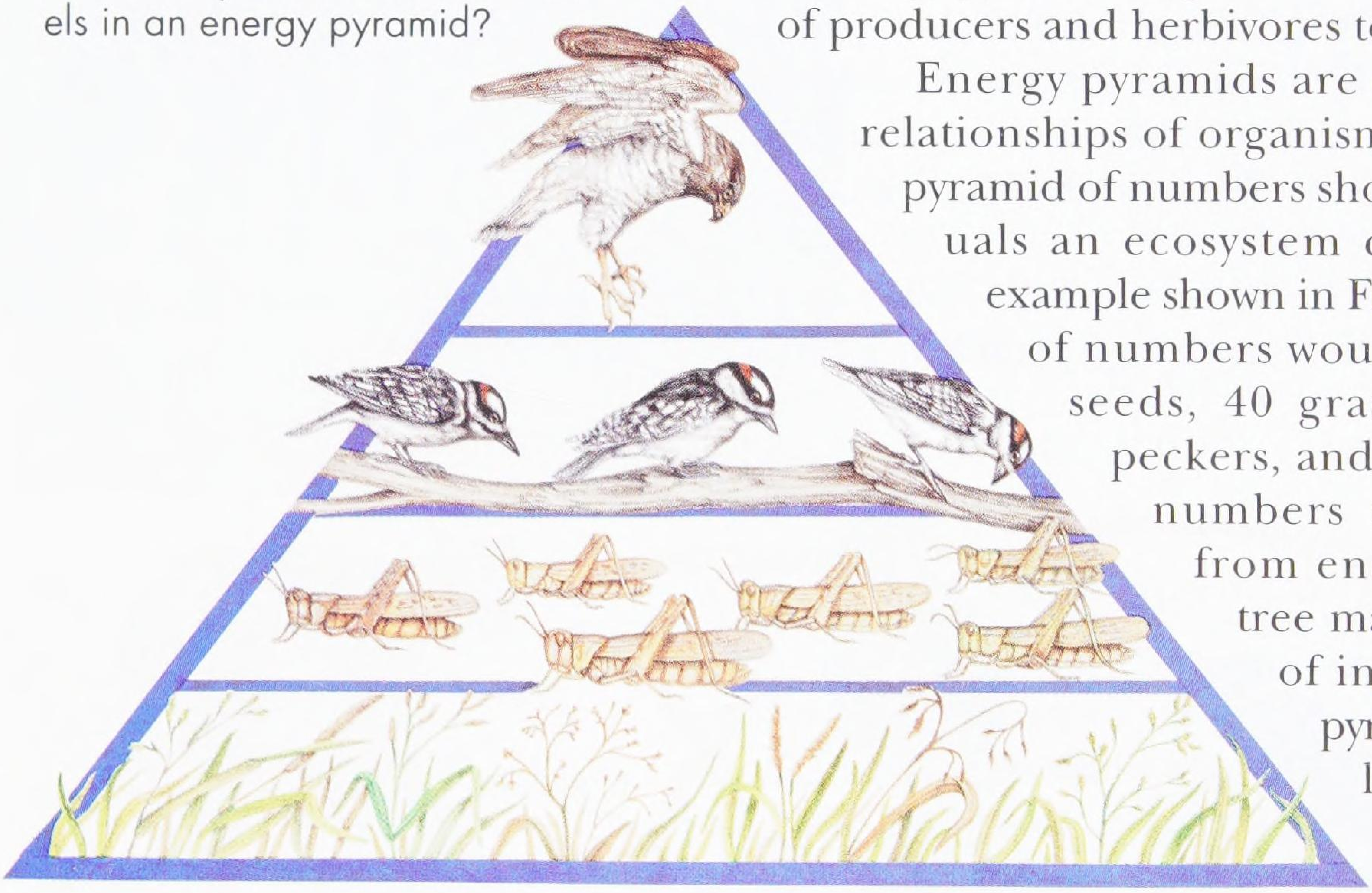


Figure 26-14. An energy pyramid usually has three or four levels. Why aren't there more levels in an energy pyramid?

SECTION REVIEW

1. Describe three relationships among organisms in a community.
2. Name and describe two examples of symbiosis.
3. **Apply:** Why are there more producers in an ecosystem than consumers?
4. **Connect to Chemistry:** Find out the meaning of biological magnification and give an example.

Skill Builder

☐ Interpreting Scientific Illustrations

Use the energy pyramid diagram above to explain the flow of energy through a pond community. If you need help, refer to Interpreting Scientific Illustrations in the **Skill Handbook** on page 693.

Abiotic Factors in the Biosphere

26-3

Objectives

- Describe how materials in the biosphere are reused in a continuous cycle.
- Diagram the cycles of water, carbon, oxygen, and nitrogen in the biosphere.
- Discuss the importance of recycling these materials in the biosphere.

New Science Words

water cycle
carbon-oxygen cycle
nitrogen cycle

Cycles of Matter

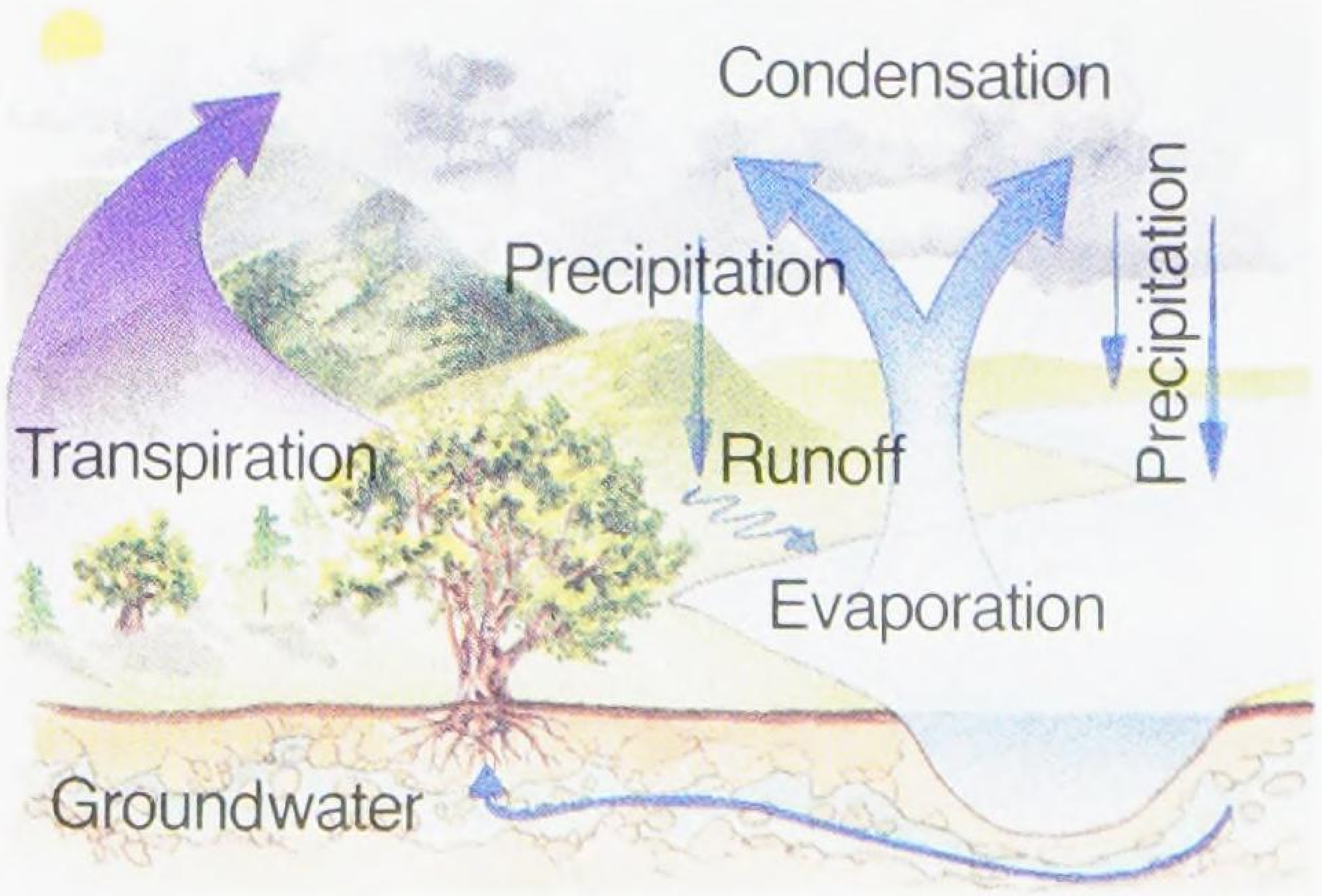
Figure 26-15 shows fungi growing on a fallen tree. Fungi are decomposers. When decomposers break down waste materials and dead organisms for energy, they return carbon, oxygen, nitrogen, and other materials to the biosphere. Producers reuse these materials to make more food that is eaten by consumers. You know that energy is used as it moves through a food chain. Unlike energy, the chemical elements that make up all organisms are used over and over again. Organisms today are using the same materials that have been used since life began. Each time a substance is used, decomposed, and returned to the environment, a cycle is completed. In a cycle, the last step brings the process back to its starting point, and the cycle occurs again and again. In the biosphere, the most important materials to life on Earth are recycled. These materials are water, oxygen, carbon, and nitrogen.

Figure 26-15. Decomposers like these fungi break down dead organisms and help cycle oxygen, nitrogen, and carbon in the biosphere.

The Water Cycle

The continuous movement of water in the biosphere is called the **water cycle.** Trace the steps of the water cycle in Figure 26-16 as you read. The sun's energy causes some of the water in soil, oceans, lakes, rivers, and living organisms to evaporate and become water vapor in the air. As the water vapor in the air cools, it condenses and changes to water droplets and forms clouds. The water from the

Figure 26-16. Water cycles through evaporation, condensation, and precipitation.



clouds returns to Earth as precipitation in the form of rain, snow, sleet, or hail. Then the cycle starts over again. You could describe the water cycle as three steps: evaporation, condensation, and precipitation.

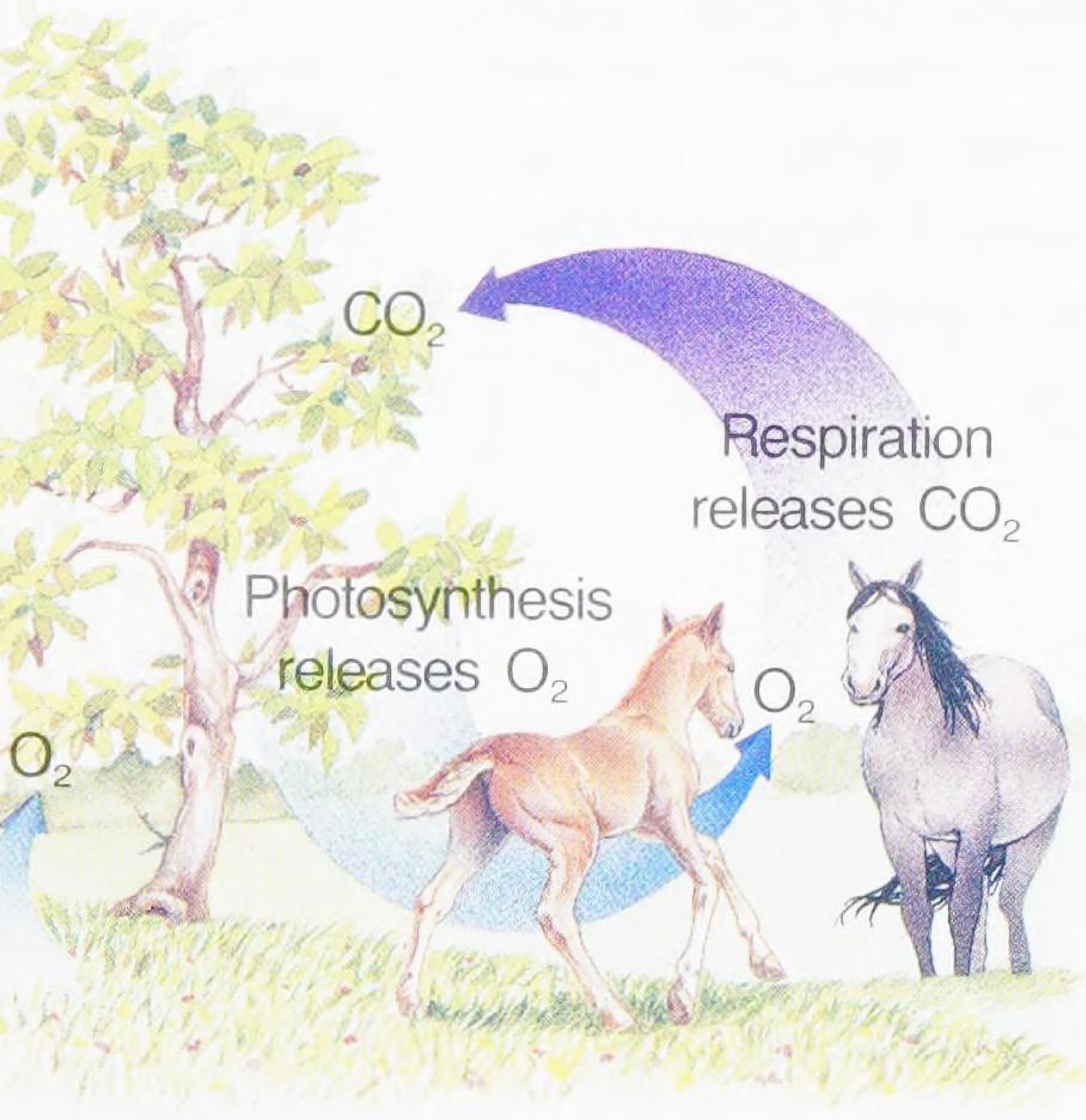


Figure 26-17. In the carbon-oxygen cycle, carbon and oxyen are recycled continuously during photosynthesis and respiration.

The Carbon-Oxygen Cycle

Many other materials in the biosphere are part of cycles. The continuous movement of carbon dioxide and oxygen between the surface of Earth and the air is called the **carbon-oxygen cycle.** You can follow the carbon-oxygen cycle in Figure 26-17. During the process of photosynthesis, plants absorb carbon dioxide from the air and release oxygen. Plants, animals, and most other organisms use oxygen for respiration. Carbon dioxide is given off and returned to the cycle. Decomposers break down the carbon compounds in dead organisms and wastes and release carbon dioxide to the air. Organisms that do not decay are compressed underground. Over millions of years, they form fossil fuels such as coal, oil, and gas. When these fuels are burned, carbon dioxide again enters the air.

TECHNOLOGY

Monitoring Mayflies

The source of water pollution in streams is hard to detect because the pollutants are diluted by water. Pollutants concentrate in fish tissue, which makes detection easier, but fish move too much to be helpful in detecting the source of water pollution.

In a process called biomonitoring, scientists now evaluate the health of streams by looking at the organisms that live there. Macroinvertebrates, such as mayflies, caddisflies, and stoneflies, remain in one location and have differing tolerances to pollution. Scientists collect samples of organisms from the stream bed and count the kinds and numbers of macroinvertebrates found. Mayflies are very sensitive to pollution. Large numbers of these show a healthy stream. Aquatic earthworms and midges tolerate pollution, so streams with more of these organisms may be in trouble!

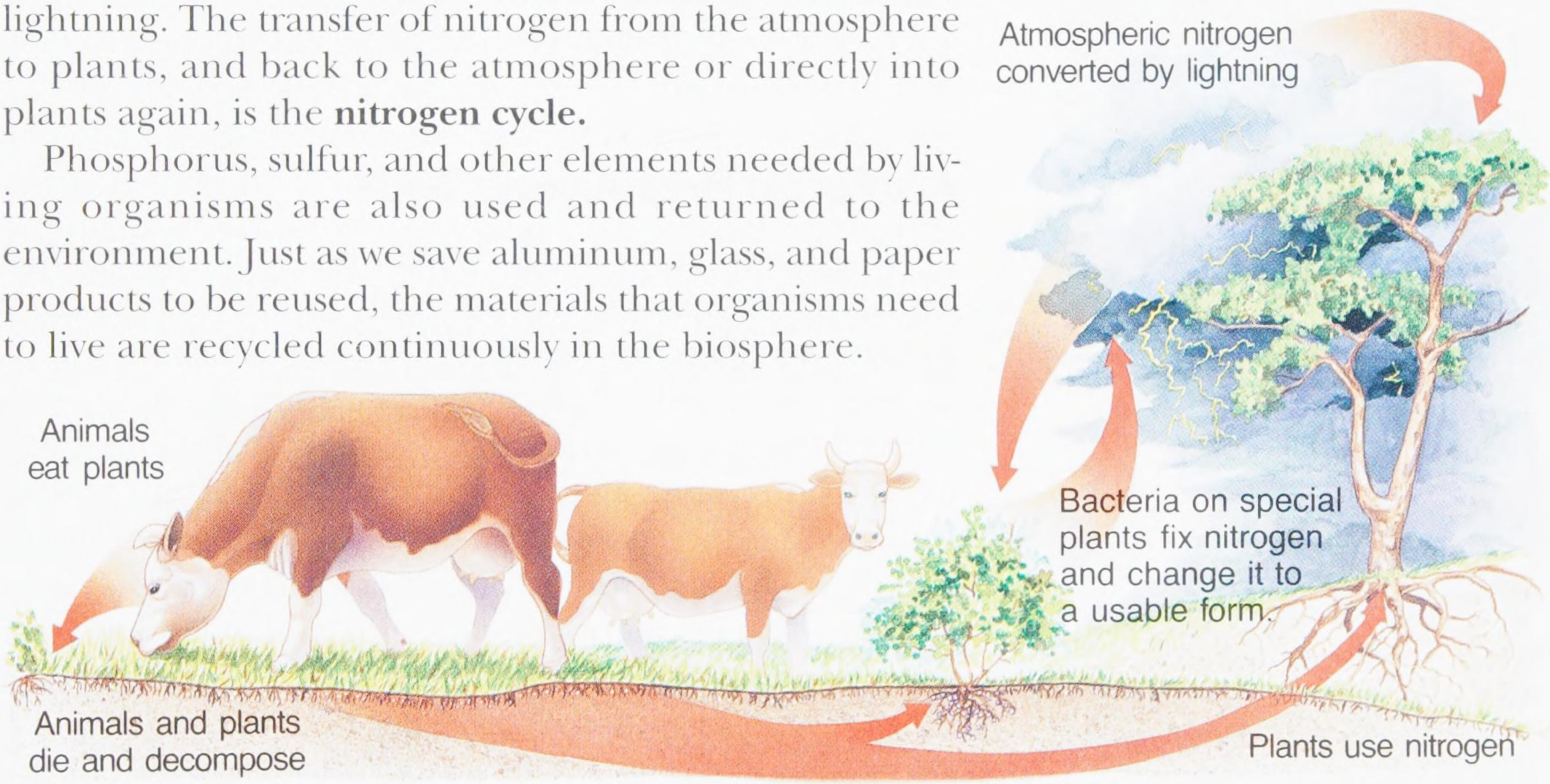
Think Critically: Most macroinvertebrates live less than a year. Why is this trait useful in biomonitoring?

The Nitrogen Cycle

Nitrogen is an important material needed by organisms to make proteins. Even though nitrogen gas makes up 78 percent of the atmosphere, most living organisms cannot use nitrogen in this form. It has to be combined with other elements in a process called nitrogen fixation. You can see in Figure 26-18 how nitrogen is converted into usable compounds by bacteria associated with plants. A small amount is changed into nitrogen compounds by lightning. The transfer of nitrogen from the atmosphere to plants, and back to the atmosphere or directly into plants again, is the **nitrogen cycle.**

Phosphorus, sulfur, and other elements needed by living organisms are also used and returned to the environment. Just as we save aluminum, glass, and paper products to be reused, the materials that organisms need to live are recycled continuously in the biosphere.

Figure 26-18. Nitrogen can be cycled from bacteria on plant roots to plants, then to animals, and directly back to plants again as a result of decomposition.


Atmospheric nitrogen converted by lightning
Animals eat plants
Bacteria on special plants fix nitrogen and change it to a usable form.
Animals and plants die and decompose
Plants use nitrogen

SECTION REVIEW

1. Describe how materials move through the biosphere.
2. Describe the nitrogen cycle.
3. Explain the relationship between the cycling of oxygen and the cycling of carbon in the biosphere.
4. **Apply:** Do you think that fossil fuels are still being formed today? Why?
5. **Connect to Chemistry:** Find out about the role of phosphorus in a pond community. What happens to the pond if excess phosphorus is present?

Sequencing

Skill Builder

Sequence the steps in the carbon-oxygen cycle. If you need help, refer to Sequencing in the **Skill Handbook** on page 680.

SCIENCE & SOCIETY

26-4 Friendly Fires

New Science Words

controlled burns

Objectives

- Describe the role of controlled fires in forests and why the fires are controversial.
- Identify reasons both for and against the use of controlled burns in areas where people live.

In Your JOURNAL

Using library resources, research several controlled burns. **In your Journal,** write a paragraph on your position, for or against controlled burns.

Are Forest Fires Always Bad?

What comes to your mind first when you think of forest fires? You may think about animals such as deer running terrified through the forest, or blackened stumps of trees and scorched ground where nothing can grow. A burned forest looks so stark and damaged, it seems it will never be the same again. What most of us don't realize is that some forests actually require such fires to maintain their character. Some pine species have evolved ways to cope with periods of fire. Jack pine and lodgepole pine trees have cones that don't open to release seeds until they have been heated in a fire!

In some types of forests, biologists conduct **controlled burns,** managed forest fires that are set periodically to control the amount of vegetation underneath the dominant forest tree species. In areas where natural fires don't occur, deep piles of dead leaves, dropped needles, and dead brush build up on the forest floor. All of this dead organic matter becomes potential fuel if a fire should start. To make sure that this organic matter doesn't build up too much, biologists sometimes start small fires to burn up the material on the forest floor. This is one way biologists hope to prevent major forest fires.

What happens to the forest animals during a controlled burn? Researchers contend that wild animals are unharmed because they move away from areas on fire. Some animals, such as the rare red-cockaded woodpecker, depend upon fires to maintain their habitat. They live in open pine stands that are often invaded by hardwood trees. Fires help to keep the hardwoods from growing in the open spaces between the pines.

Controlled burns are usually less intense and produce less heat than uncontrolled forest fires. This is another reason researchers feel that it is better to have a few controlled fires periodically than a large, out-of-control fire. However, even controlled burns sometimes cause damage to areas outside of the intended area of the burn. If the wind shifts suddenly, a fire may race toward residential areas instead of staying in the forest. Homes and businesses have burned to the ground from controlled fires as well as natural forest fires. Controlled burns also result in air pollution from smoke, and newly burned areas are eyesores to those who live nearby. It may take a few years for the burned areas to begin growing again. In the meantime, local residents see damaged forest views every day.

Biologists are very careful to set fires only at times when wind conditions are right. But people who live near national forests and parks still are concerned over the need for controlled burns. They believe controlled burns are not "controlled" at all. They also aren't convinced that forest animals are unharmed as a result of these fires.

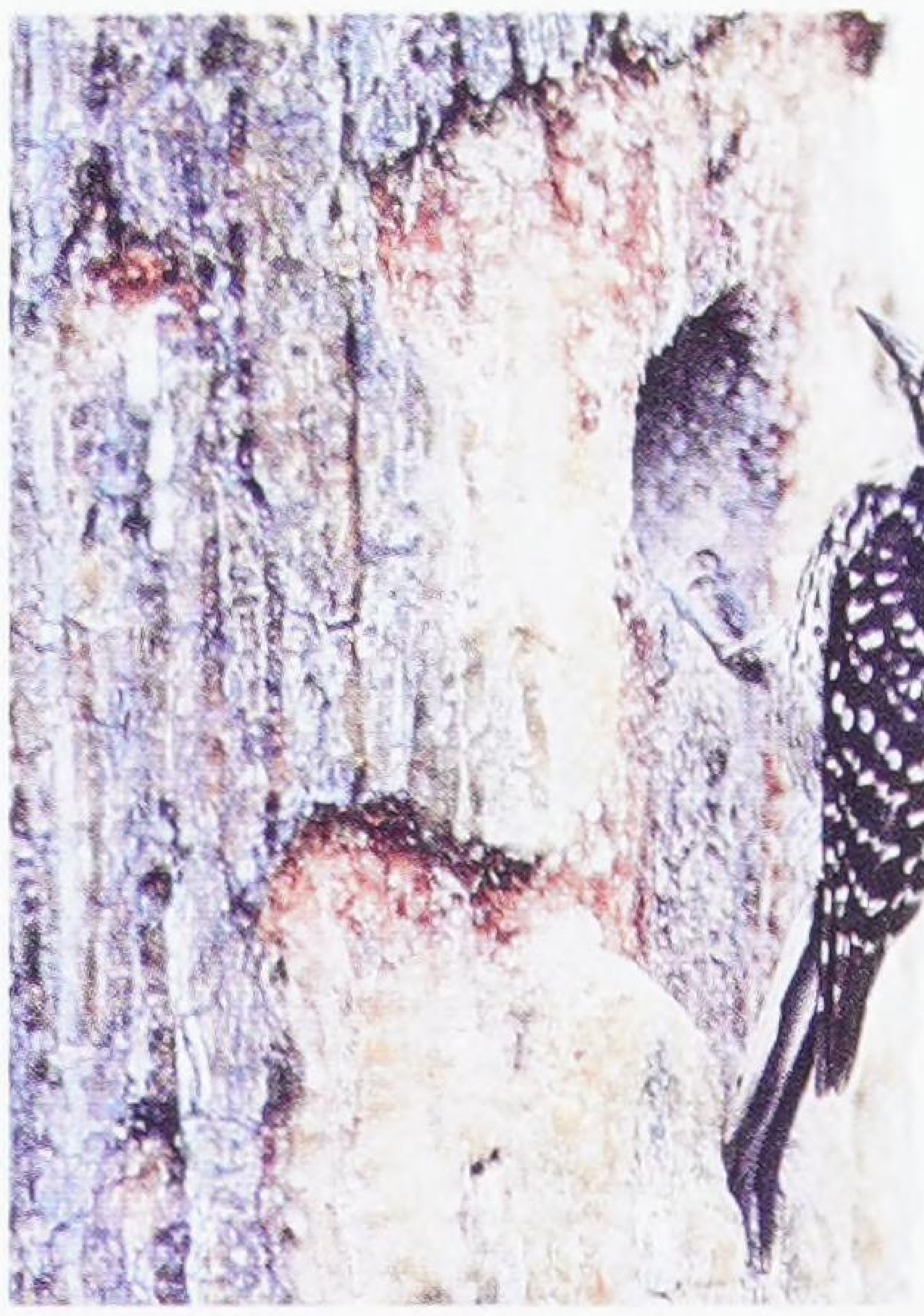


Figure 26-19. The red-cockaded woodpecker is one organism that depends on fires to maintain its habitat.

Connect to...

Chemistry

When burning takes place in the presence of enough oxygen, carbon dioxide and water are produced. Soot and smoke form when there is not enough oxygen present to burn all the carbon of the fuel. Soot is a form of carbon called graphite. Find out what other form of pure carbon is found in nature.

SECTION REVIEW

1. Name two reasons why biologists believe controlled forest fires are useful.
2. Why are local citizens often opposed to such fires?
3. **Connect to Chemistry:** Find out why there are ashes left after a piece of wood burns.

You Decide!

SCIENCE & SOCIETY

In popular vacation spots, people often build homes in scenic areas, such as high on a ridge top. Such spots are often in forested areas that are subject to uncontrollable forest fires. Many of these vacation homes are in locations that are difficult for forest firefighters to reach. Should people be permitted to build homes in these areas?

ACTIVITY 26-2

Studying an Ecosystem

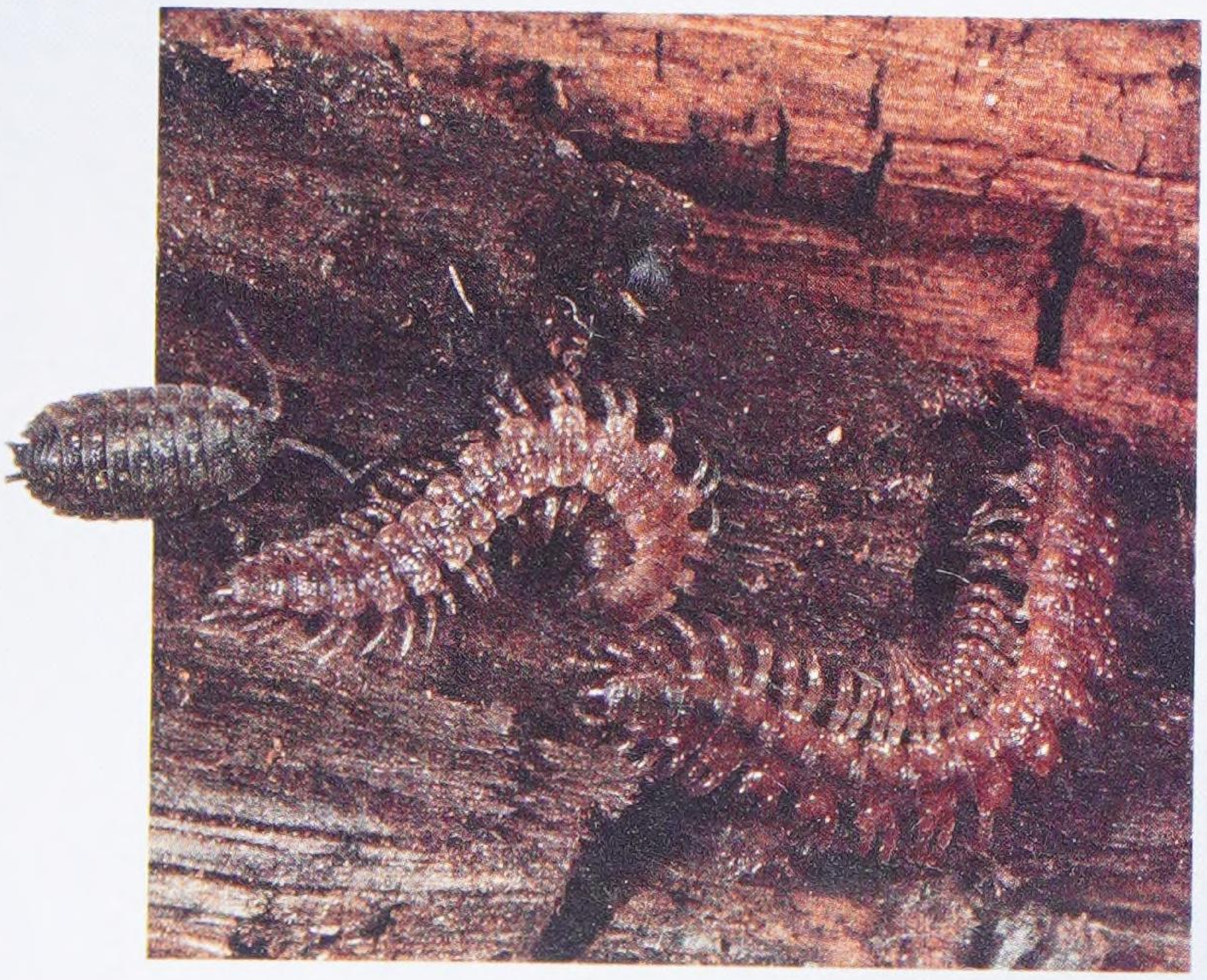
Problem: *How do you study an ecosystem?*

Materials

- graph paper
- notebook
- pencil
- binoculars
- field guides
- hand lens

Procedure

1. Choose a natural community near your school or home to be your ecosystem for study. You may choose to study a pond, a forest area in a park, a rotten log, or an area around your school.
2. Decide the boundaries of the ecosystem you are studying. Make the ecosystem a size you think you can study well.
3. Make a map or drawing of the ecosystem on graph paper.
4. *Observe* the organisms that live in the ecosystem. Use a hand lens to study small creatures. Use binoculars to study organisms you cannot get near. Look for evidence, such as tracks or feathers, of organisms you cannot see.
5. Record your observations in a table like the one shown. Make drawings. Use field guides to identify the organisms.
6. Visit the ecosystem as many times as you can and at different times of day for four weeks. Make observations and record them. Pay close attention to the relationships among organisms. Also note how the organisms interact with the nonliving environment.



Data and Observations

Date	Organisms Observed	Comments

Analyze

1. What is the ecosystem you chose?
2. Describe the nonliving environment of the ecosystem.
3. How many populations did you count?
4. Which organisms in the ecosystem are producers, consumers, or decomposers?
5. What evidence of competition did you find?

Conclude and Apply

6. *Diagram* a food web in the ecosystem.
7. *Predict* what might happen if a population of producers was removed from the community.
8. *Predict* what might happen if either the predators or the decomposers were removed from the community.
9. *Identify* relationships among the organisms in the ecosystem, such as predator-prey, mutualism, or parasitism.
10. *Infer* how the nonliving environment is important in the ecosystem.
11. *Predict* what might happen if the nonliving environment changed suddenly.
12. Based on your observations, what conclusions can you make about studying an ecosystem?

CHAPTER

REVIEW

SUMMARY

26-1: Organisms and Their Environments

1. The biosphere is the part of Earth where all life is found, and it consists of biotic (living) factors as well as abiotic (nonliving) factors such as air, soil, water, and sunlight.

2. Populations are made up of all the members of a species living in the same place at the same time. A community includes all the populations of the area. The community and the abiotic factors make up the ecosystem.

3. An organism lives in its habitat within a community. The role or job of an organism within a community is its niche.

26-2: Biotic Relationships

1. Organisms have relationships with each other. These relationships include feeding relationships and symbiotic relationships.

2. Energy in food is transferred through a community in food chains. Overlapping food chains are food webs. Organisms are part of many food chains or webs in a community.

3. Energy stored in food moves through the community from producers to consumers to decomposers. At each level only a small amount of the energy consumed is available to the next level of organism.

26-3: Abiotic Factors in the Biosphere

1. Materials in the biosphere are cycled in order for organisms to survive.

2. Water, carbon, oxygen, and nitrogen are recycled in the environment.

3. Many of the materials needed by organisms are recycled.

26-4: Science and Society: Friendly Fires

1. Controlled forest fires are set to reduce the risk of uncontrolled fires.

2. Even controlled fires may become uncontrolled and damage areas where people live.

KEY SCIENCE WORDS

a. **abiotic factors**
b. **biosphere**
c. **biotic factors**
d. **camouflage**
e. **carbon-oxygen cycle**
f. **community**
g. **competition**
h. **controlled burns**
i. **ecology**
j. **ecosystem**
k. **energy pyramid**
l. **food chain**
m. **food web**
n. **habitat**
o. **mimicry**
p. **niche**
q. **nitrogen cycle**
r. **population**
s. **population density**
t. **water cycle**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. living things in the environment
2. number of organisms in an area
3. all parts of Earth with life
4. job of a species in an environment
5. the cycle that includes evaporation, condensation, and precipitation
6. copying another organism's behavior or appearance
7. all the populations in an ecosystem
8. interaction of abiotic and biotic factors
9. series of overlapping food chains
10. where an organism lives in an ecosystem

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. All are abiotic factors except _______.
   - **a.** animals
   - **b.** air
   - **c.** sunlight
   - **d.** soil
2. A coral reef and an oak-hickory forest are examples of a(n) _______.
   - **a.** niche
   - **b.** habitat
   - **c.** community
   - **d.** ecosystem
3. The ________ is made up of all populations in an area.
   - **a.** niche
   - **b.** habitat
   - **c.** community
   - **d.** dominant species
4. The number of individuals in a given area is called population _______.
   - **a.** clumping
   - **b.** size
   - **c.** spacing
   - **d.** density
5. An example of a consumer is _______.
   - **a.** tree
   - **b.** moss
   - **c.** grass
   - **d.** rabbit
6. In an ecosystem, _______ get the most energy.
   - **a.** omnivores
   - **b.** herbivores
   - **c.** decomposers
   - **d.** producers
7. _______ is a relationship in which one organism is helped and the other harmed.
   - **a.** Mutualism
   - **b.** Parasitism
   - **c.** Mimicry
   - **d.** Camouflage
8. Photosynthesis, respiration, and the burning of fuels are all directly involved in the _______.
   - **a.** water cycle
   - **b.** nitrogen cycle
   - **c.** phosphorus cycle
   - **d.** carbon-oxygen cycle
9. Materials that are cycled in the biosphere include all of the following except _______.
   - **a.** nitrogen
   - **b.** sulfur
   - **c.** phosphorus
   - **d.** energy
10. Controlled burns of forests are needed _______.
    - **a.** for normal growth
    - **b.** to improve habitats
    - **c.** to thin out brush
    - **d.** to increase dead organic matter

USING LAB SKILLS

11. In Activity 26-1, you determined population size by sampling. Describe a procedure for determining the size of the student population in your school by sampling. Carry it out.
12. In Activity 26-2 on page 622 you studied an ecosystem. Using a covered 2L container, gravel, aged tap water, one Elodea plant, and one guppy, make an ecosystem. What are the abiotic factors in your ecosystem? What are the biotic factors?

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. What would be the advantages to humans if they ate food lower on the food chain?
14. Use Figure 26-7 on page 611 and describe two food chains of the coral reef ecosystem.
15. Explain the advantages of a mutualistic relationship by using an example.

APPLY

16. Explain the changes that would occur in biotic relationships if the density of a population increased dramatically.
17. A maggot grows within a gall formed on the goldenrod plant, eventually maturing and emerging as a fly while the goldenrod dies. What kind of relationship is this?

18. What would happen to an ecosystem if decomposers were removed?
19. Explain why energy flow is described as a pyramid.
20. Explain how photosynthesis and respiration are opposite reactions in the carbon-oxygen cycle.

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Classifying:** Classify each as producer, herbivore, carnivore, or omnivore: cow, deer, grass, shark, rabbit, bear, green algae, lion, sunflower.
2. **Making and Using Graphs:** Use the following data to graph the density of a deer population over the years. Plot the number of deer on the y-axis and years on the x-axis. Explain what may have happened to change the population density.

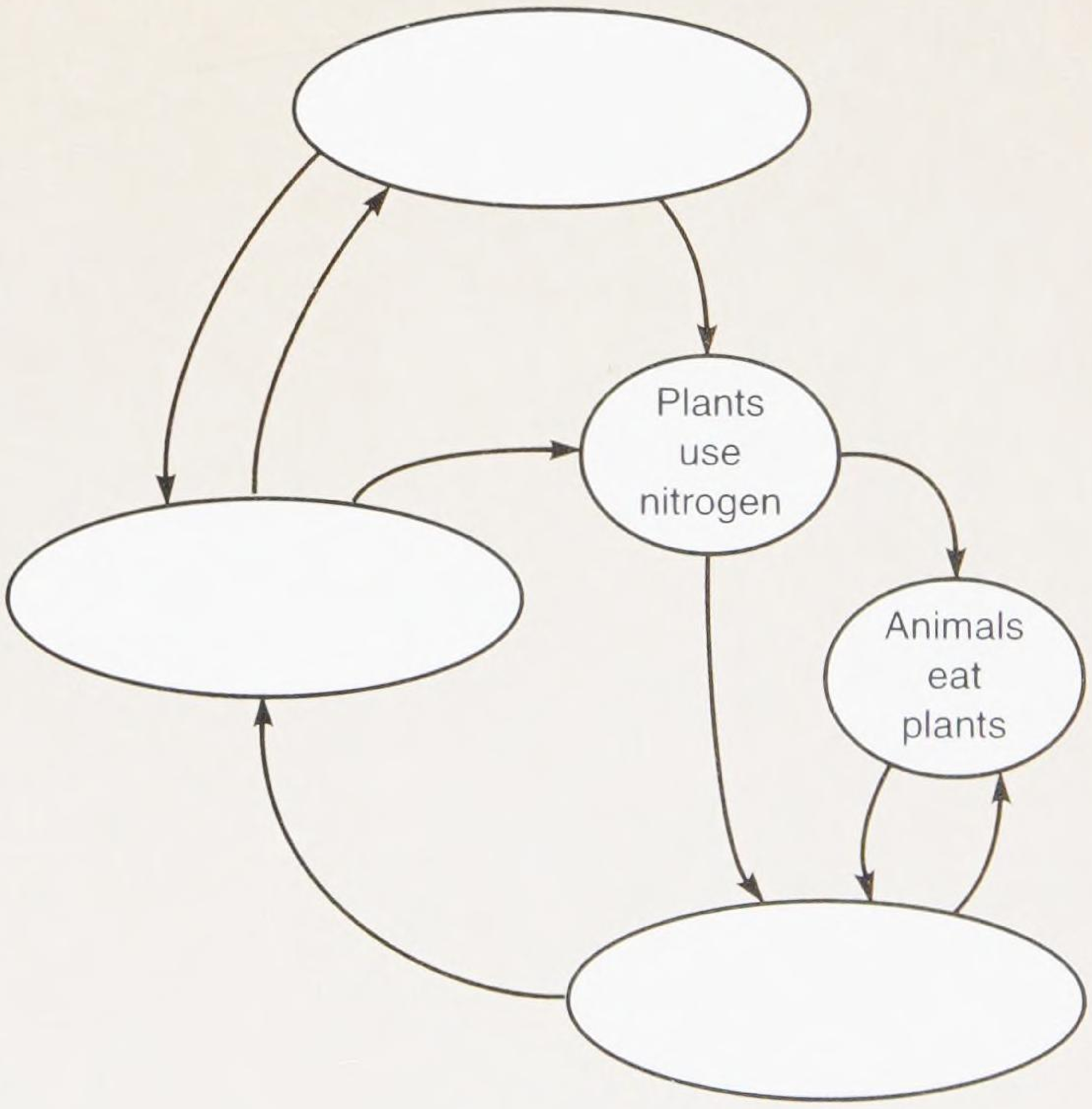
Year	Deer (in thousands) per 400 hectares
1905	5.7
1915	35.7
1920	142.9
1925	85.7
1935	25.7

3. **Concept Mapping:** Use this information to draw a food web of organisms living in a goldenrod field.

Goldenrod - sap is eaten by aphids
- nectar eaten by bees
- pollen eaten by beetles
- leaves eaten by beetles

Stinkbugs eat beetles
Spiders eat aphids
Assassin bugs eat bees

4. **Classifying:** Classify each event in the water cycle as the result of either precipitation or evaporation:
   - **a.** A puddle is gone after the rain.
   - **b.** Rain falls.
   - **c.** Snow covers the mountainside.
   - **d.** A lake becomes shallower.
5. **Concept Mapping:** Fill in the correct terms to show the nitrogen cycle.

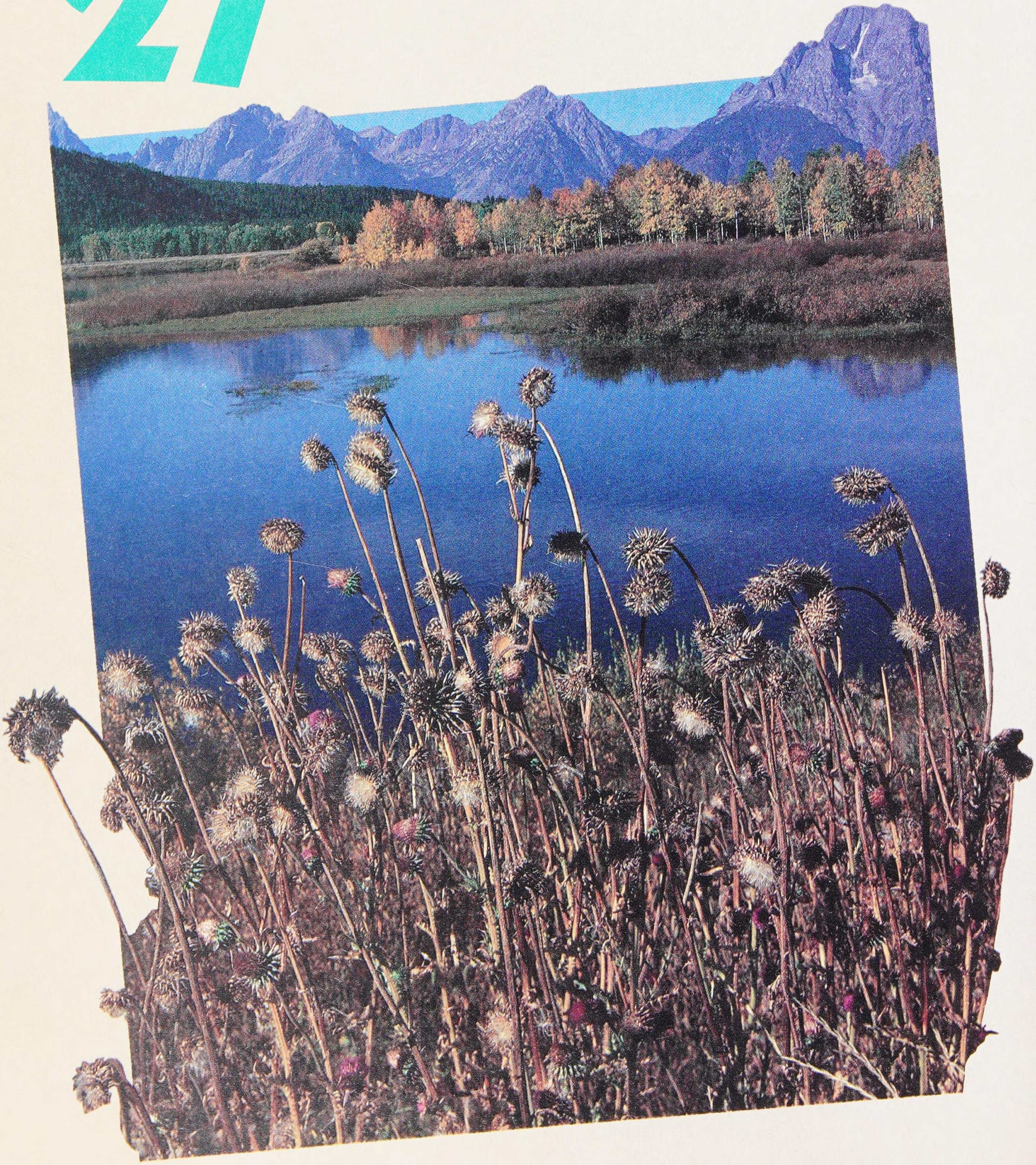


PROJECTS

1. Continue observing the ecosystem from Activity 26-2. Make observations several times a month for a year. Record your observations in your Journal.
2. Research the phosphorus cycle. Find out what role phosphorus plays in an algal bloom.

CHAPTER

27 Biomes



Do you live in an area that has pine forests, mountains, and lakes? Do you live near the ocean? You know that all life exists in the biosphere. But do you know where in the biosphere you live?

FIND OUT!

Do this simple activity to find out what part of the biosphere you live in.

Study a globe or a world map. Locate the country, state, and city where you live. What is the latitude of your state? Locate the equator. *Determine* where you live in relation to the equator. Do you have four seasons each year? What is the climate where you live?

Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 27-1 Factors That Affect Biomes
- Limiting Factors
- Succession

Section 27-2 Land Biomes
- Land Biomes
- Tundra
- Northern Coniferous Forests
- Deciduous Forests
- Grasslands
- Deserts
- Tropical Rain Forests

Section 27-3 Water Ecosystems
- Marine Ecosystems
- Freshwater Ecosystems

Section 27-4 Science and Society
Coastal Wetlands
- Wetlands or Wastelands?

Previewing Science Skills

- In the **Skill Builders,** you will hypothesize and make a concept map.
- In the **Activities,** you will study maps, observe, use a table, experiment and graph.
- In the **MINI-Labs,** you will hypothesize and interpret data.

What's next?

Now that you have located where you live, learn how the climate, soil, and other abiotic factors of an area help determine what living things are found there and where they are located.

27-1 Factors That Affect Biomes

New Science Words

limiting factor
succession
primary succession
secondary succession
climax community

Objectives

- Identify and describe limiting factors.
- Define succession and differentiate between primary and secondary succession.
- Describe climax communities.

Limiting Factors

Have you ever seen a lobster like the one in Figure 27-1? Lobsters are found only in marine environments. The animal pictured below looks like a lobster, but it is a freshwater crayfish. What would happen to the lobster if you placed it in a freshwater stream? What would happen to the crayfish if you placed it in the ocean?

Most organisms live in a place that is, for them, the best place to live. Each species has adapted to a set of biotic and abiotic factors in its environment. Lobsters have adapted to a marine environment and cannot survive in fresh water. For lobsters, fresh water is a limiting factor. A **limiting factor** is a condition that determines the survival of an organism, population, or species in its environment. Any factor that limits the number, distribution, reproduction, or existence of organisms is a limiting factor. What are other limiting factors for the lobster?

In an oak-hickory forest, the mouse population is limited by the amount of thistle seed available for food, and the availability of mates and nesting sites. Competition among the mice for seeds, mates, or nesting sites, as well as predation by owls and hawks, are biotic factors that may limit the size of the mouse population. Abiotic factors that may become limiting include temperature, amount of sunlight, water, wind, elevation, or currents.

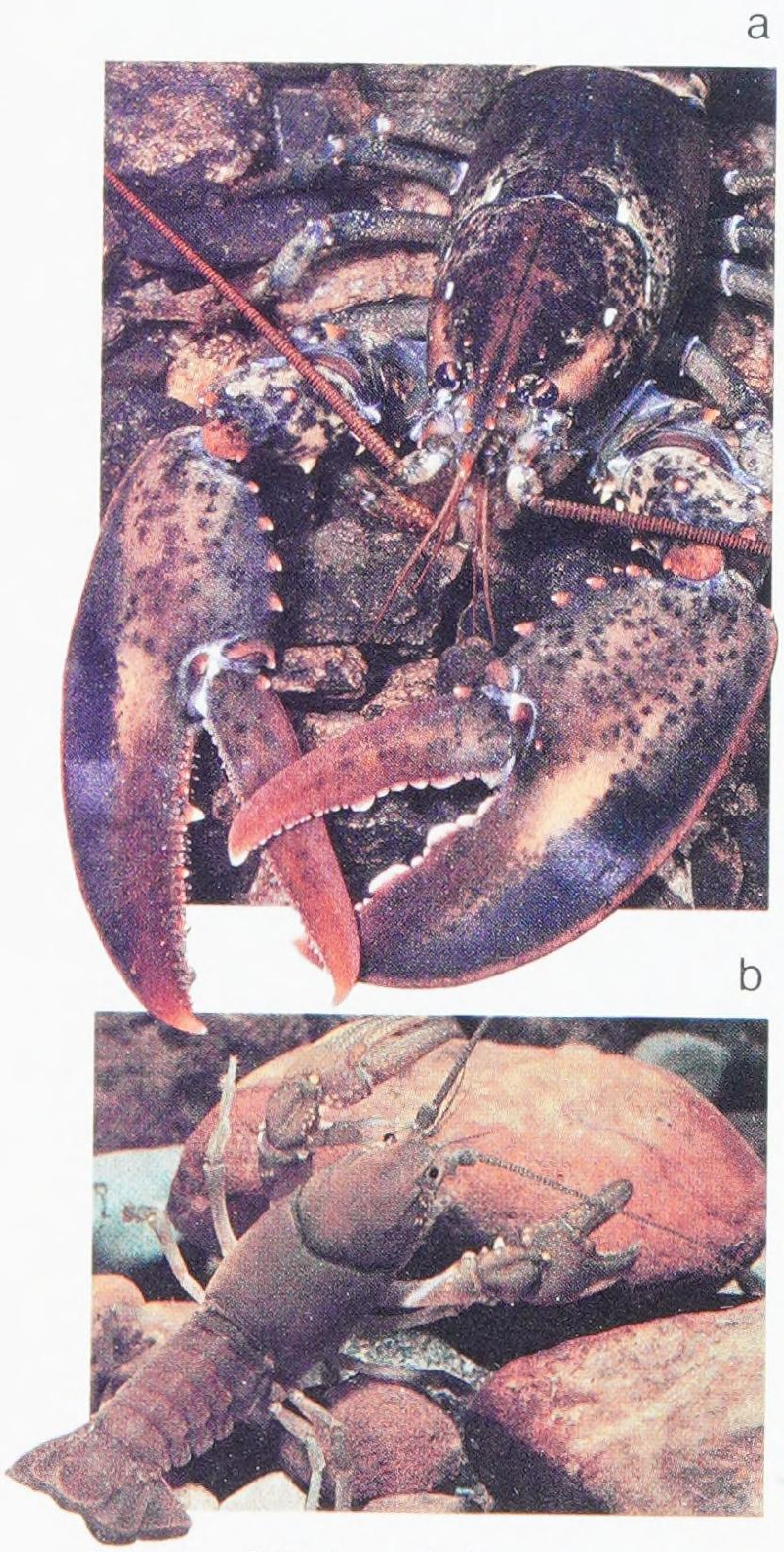


Figure 27-1. A lobster is adapted to a marine environment, whereas crayfish live in freshwater ecosystems.

Succession

Look at the field with scattered pine tree seedlings in Figure 27-2. In a few years, these seedlings will become trees, and eventually a pine forest will stand where the field is now. Birds, mice, squirrels, chipmunks, and many other animals and plants will grow in the forest. Seedlings of tree species such as oaks, hickories, and elms may begin to grow in the shade underneath the pines. As the pine trees mature and die, the forest may become an oak-hickory forest. This gradual change in a community over time is called **succession.** Succession occurs in a community in an orderly process. Ecologists have identified two types of succession: primary succession and secondary succession.

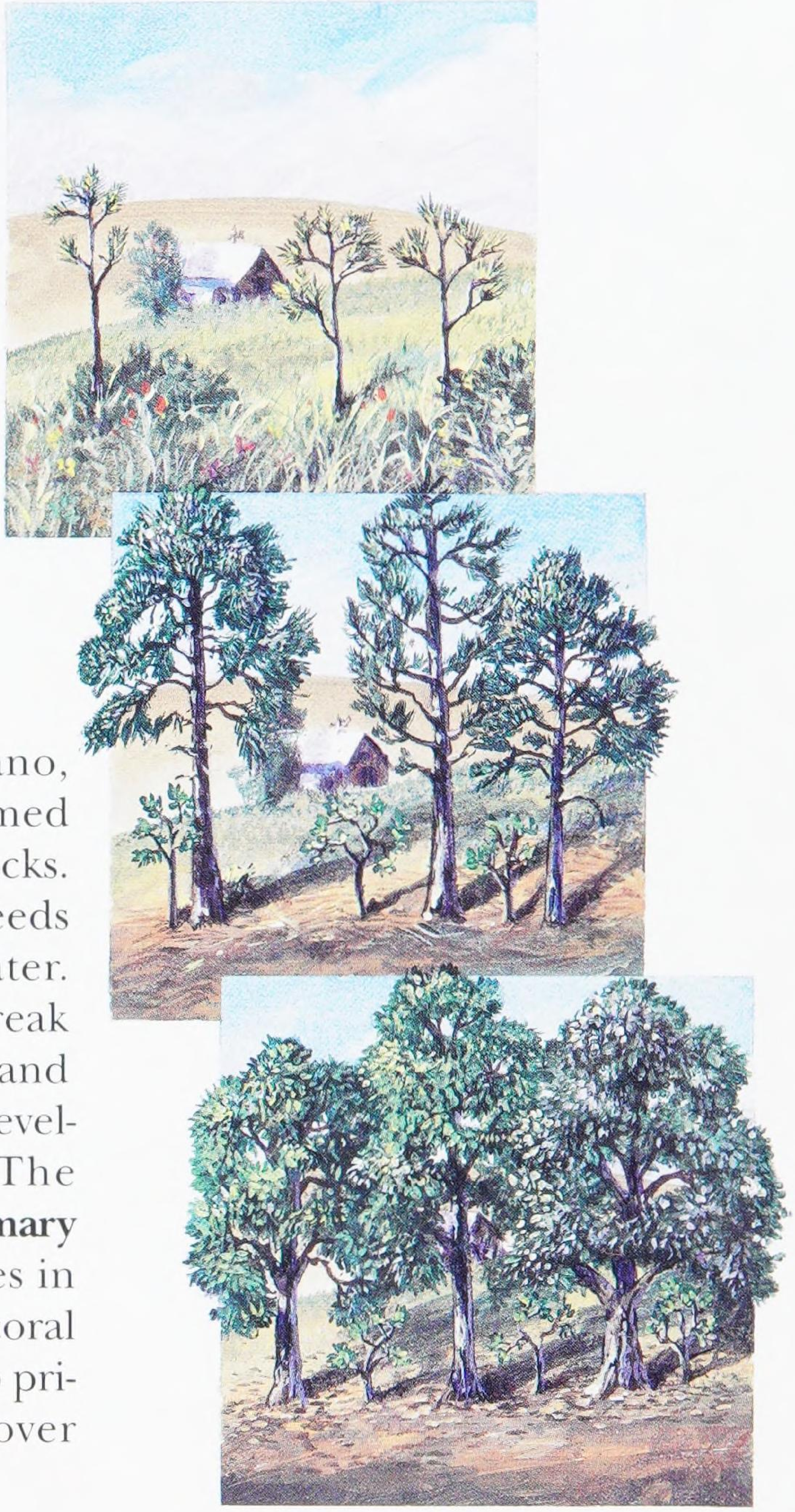


Figure 27-2. Succession in an open field begins with scattered pine seedlings. Years later the field is a pine forest, and eventually it becomes an oak-hickory forest.

Primary Succession

On a volcanic island, lava flows out of the volcano, cools, and forms new land. Many islands were formed this way. Over time, dust and ash settle on the lava rocks. Soil particles, bacteria, pollen, spores, and plant seeds may be carried to the island by wind, birds, or water. Pioneer species such as mosses begin to grow and break down the rock. Dead plants add organic materials, and soil begins to form. Eventually plant communities develop, and animals that eat these plants move in. The volcanic island is undergoing primary succession. **Primary succession** is the development of new communities in newly created land areas. Volcanic islands, exposed coral reefs, and human-made ponds or reservoirs undergo primary succession. Primary succession may occur over hundreds or thousands of years.

Secondary Succession

The succession of a community is also disturbed by fire, floods, earthquakes, and human activities such as logging or mining. If the disturbed area is then abandoned or left alone, succession may begin again. A pasture abandoned by a farmer may be invaded by grasses, shrubs, and trees in a process called secondary succession. In **secondary succession,** a disturbed area gradually returns to its previous condition. After fires destroyed parts of Yellowstone National Park in 1988, new plants began to grow through the ashes on the forest floor. Ecologists are studying this case of secondary succession very carefully to see what organisms return to the disturbed areas, and in what order.

Connect to...
Earth Science

The eruption of Mount St. Helens killed practically all the local plant and animal life. Find out what plants and animals have returned to the area.

ACTIVITY 27-1

Interpreting a Map

Problem: *How do you use a hardiness zone map?*

Materials

- pencil and paper

Procedure

1. Study the hardiness zone map below. Hardiness zone maps show places of similar climates and vegetation type.
2. *Examine* the table under Data and Observations. This gives the northern limit to which some plants can live.
3. *Use the map and the table* to answer the questions that follow.

Data and Observations

Plant	Northern Zone Limit
White pine	2
Forsythia	2
Azalea	3
Rhododendron	2
Pyracantha	4
Chinese holly	3
Passion flower	5 and 6

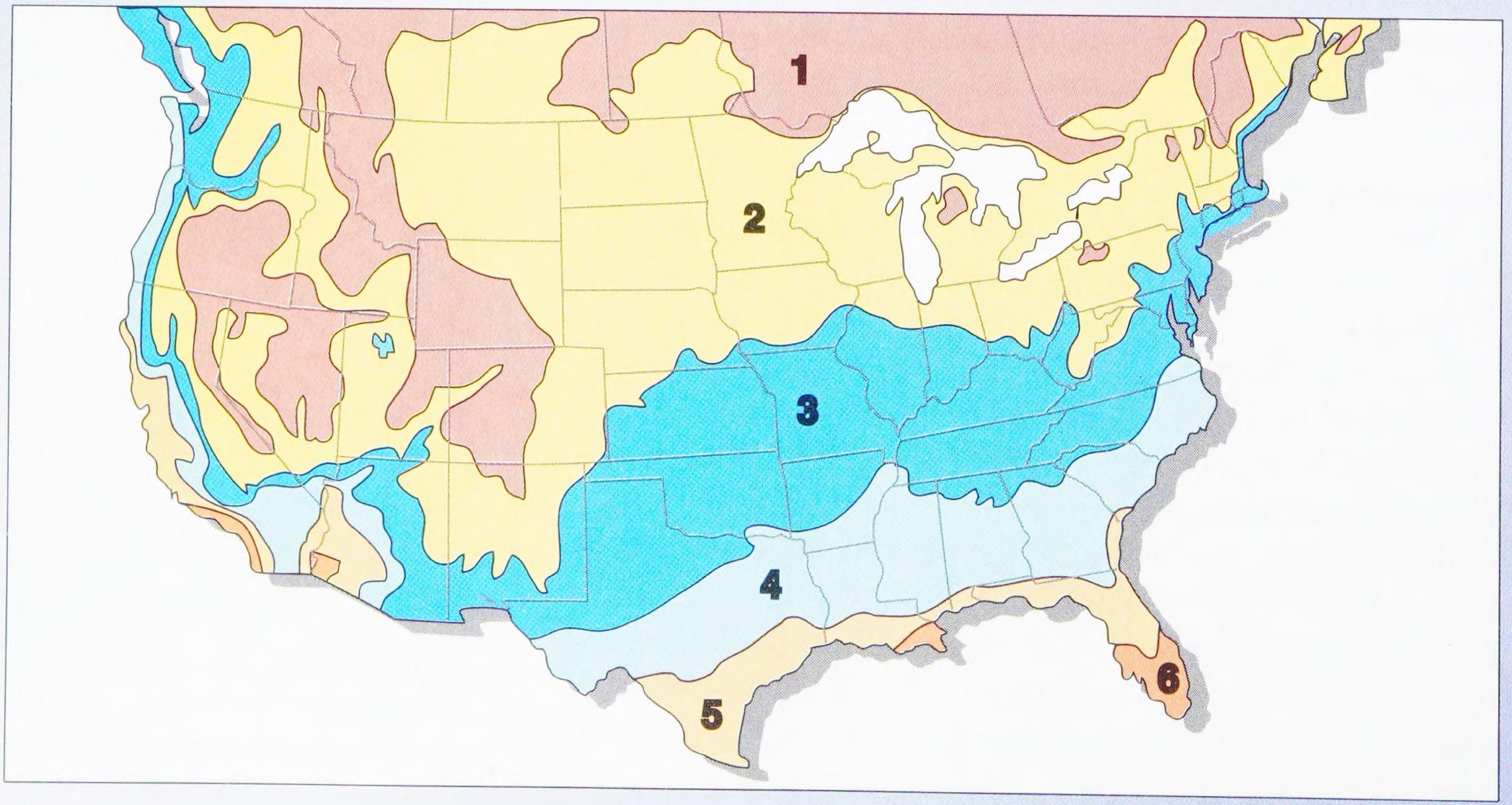
Note: Zone 1 is coldest; zone 6 is warmest.

Analyze

1. In which zone do you live?
2. Which zone crosses the most states?
3. Which plants grow the farthest north?
4. Which plants cannot grow in Canada?
5. What are the states in zone 6?

Conclude and Apply

6. Could people living in Ontario use azaleas in their landscapes?
7. Could Chinese holly grow in Oklahoma?
8. How would a gardener use the map?
9. How do you use a hardiness zone map?



Climax Community

What do a pine forest, oak-hickory forest, and desert have in common? Any of these ecosystems may be the final stage of succession in a particular area on Earth. Succession in any one place continues until it reaches a stage where the same species continue to grow and reproduce over and over. A community that is able to maintain a balance between abiotic and biotic factors and remain stable is a **climax community.** For any area, the type of climax community that develops is determined by the limiting factors of that environment. Where rainfall is limited and daytime temperatures are very hot, a desert may be the climax community. A climax community is made up of organisms that are adapted to the climate and soil conditions. You can see why climax communities are not the same everywhere.

During each stage of succession, the members of the community change the environment, making it more or less favorable for the present populations. A sunny field favors the growth of pine seedlings, but a pine forest does not. A pine forest favors oak and hickory seedlings. Oak and hickory forests, however, favor oak and hickory seedlings. Oak and hickory forests often are climax communities. A climax community will survive as long as environmental conditions remain the same.

SECTION REVIEW

1. Describe limiting factors and give three examples.
2. What is meant by the term *climax community*?
3. **Apply:** A beaver builds a dam across a stream and creates a pond. Would succession in this pond be primary or secondary succession? Why?
4. **Connect to Chemistry:** Oxygen is an abiotic factor that may become limiting. In what forms does oxygen occur in aquatic environments and on land?

MINI-Lab

How do communities change?

Use the data below to explain how tree species changed over 50 years in an area that started as an abandoned field and became a forest.

	Age of Area (years)		
Tree Species	5	20	50
Black Cherry		✓	✓
Butternut Hickory			✓
Persimmon	✓	✓	
Sassafras	✓	✓	
Shagbark Hickory			✓
Red Oak			✓
White Oak			✓
Yellow Chestnut			✓
White Ash		✓	✓
Winged Elm		✓	✓

Explain why some trees are no longer present after 50 years and why some trees did not appear until 20 or 50 years had gone by. Be sure to give the names of the trees in your answer.

Hypothesizing

Skill Builder

Make a hypothesis as to what would happen to succession in a pond if the pond owner removed all the cattails and reeds from around the pond edges every summer. If you need help, refer to Hypothesizing in the **Skill Handbook** on page 686.

27-2 Land Biomes

New Science Words

climate
biomes
tundra
permafrost

Objectives

- Define biomes.
- Identify the location of the major land biomes.
- Describe the climate, dominant plant types, and characteristic animals of the major land biomes.

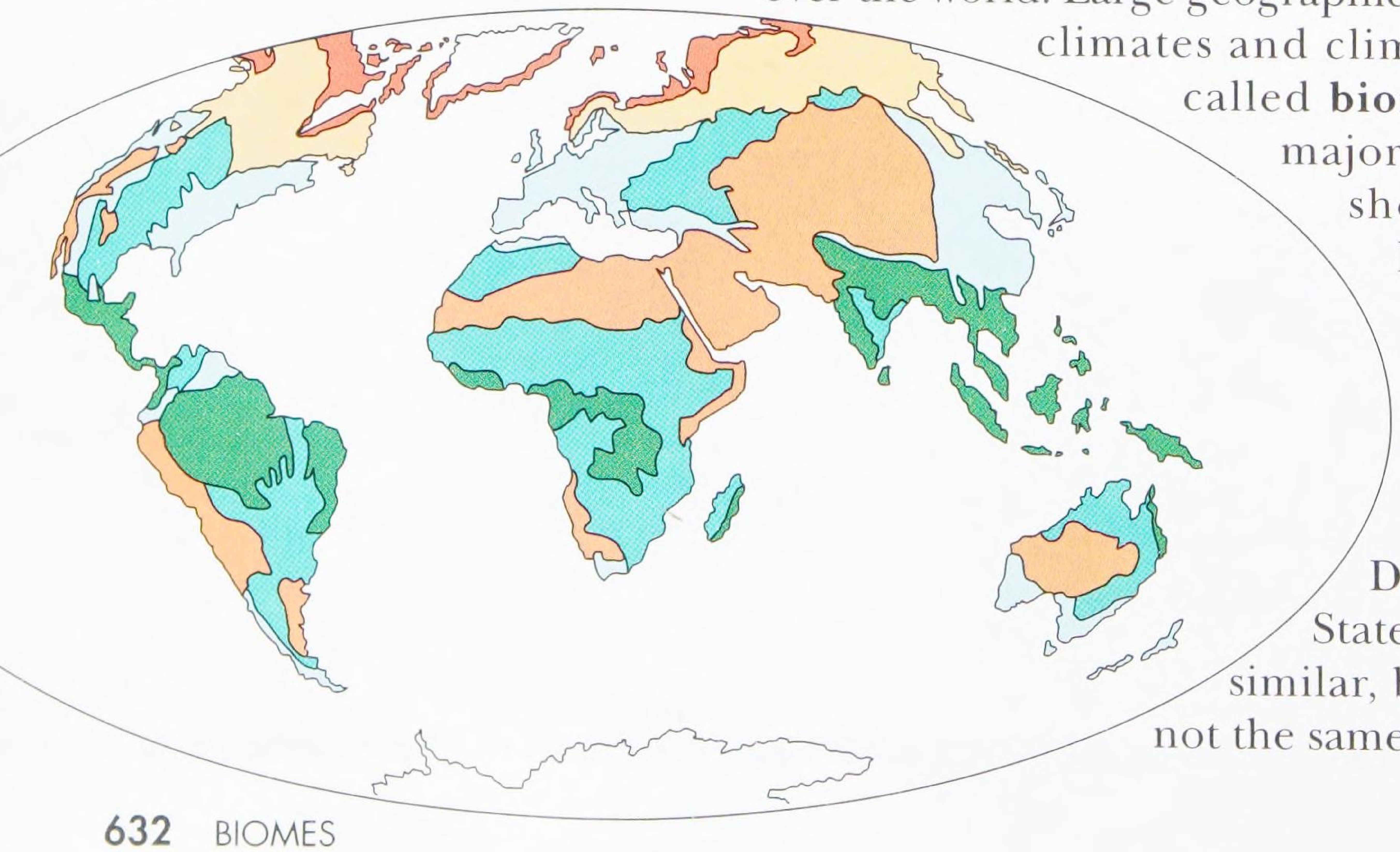
Land Biomes

What are biomes?

Imagine that you could get on a train at the equator and travel north or south to the poles. What changes in the environment could you see from the train's windows? Palm trees and banana trees are found at the equator, whereas magnolias, laurels, and pecan trees are found in temperate climates. Forests of pine, spruce, and firs would be seen in colder regions near the poles. At the poles, trees would disappear altogether! These changes in forest communities as you travel away from the equator are the result of gradual changes in climate. **Climate** is the average condition of the weather in an area, as determined by rainfall, temperature, and amount of sunlight—all abiotic factors. These abiotic factors as well as other limiting factors help determine what species can survive in a particular environment. These factors also help determine the structure of climax communities all over the world. Large geographic areas that have similar climates and climax communities are called **biomes** (BI ohmz). The major biomes on Earth are shown in Figure 27-3. Each major biome shares similar climate conditions, but the specific organisms found in each community will be different. Deserts in the United States and Africa look very similar, but the organisms are not the same.

Figure 27-3. The locations of the six major land biomes on Earth can be identified by using the key below.

🟥 Tundra
🟨 Northern coniferous forest
⬜ Deciduous forest
🟦 Grassland
🟩 Tropical rain forest
🟧 Desert



Tundra

Can you picture a region that receives little precipitation yet is covered with snow and ice for nine months each year? The **tundra** (TUN drah) is a cold, dry, treeless biome where the sun barely rises during the six to nine winter months. It is located in the far northern parts of North America, Europe, and Asia and is the most continuous of Earth's biomes. Nearly 20 percent of Earth's land area is covered by tundra.

Low temperatures and a short growing season are the major limiting factors in the tundra. Precipitation in the tundra averages less than 25 cm yearly. Temperatures drop to minus 40°C and keep the ground frozen for most of the year. In the short summer months, the snow melts and the upper layer of soil thaws. The soil underneath that remains permanently frozen is called **permafrost.** Permafrost prevents soil from absorbing water.

What kind of organisms live in such a harsh environment? Tundra plants include lichens, mosses, and flowering plants such as cranberries. Insects such as mosquitoes and blackflies grow in vast numbers. Ducks, geese, and songbirds feed on the abundant insects. Tundra mammals include caribou, reindeer, musk oxen, and arctic foxes. Many animals come for the summer, then migrate to warmer regions in the fall. Other animals remain throughout the year. Arctic hares, polar bears, and snowy owls have white fur and feathers that provide camouflage in the snow. Why is white fur an advantage for a predator like the polar bear in the tundra?

Northern Coniferous Forests

The northern *coniferous forest biome* has as its dominant plants cone-bearing evergreen trees such as pines, firs, spruces, and cedars. These forests cover large parts of northern Europe, Asia, and North America. Winters are long and cold with heavy snows. Even though summers are short, they are longer and warmer than summers in the tundra. In these forests, the ground thaws in the summer, making it possible for trees to grow. Rainfall in this biome ranges from 50 to 125 cm yearly.

Because coniferous forests are dense, little light penetrates to the soil, so there are few shrubs or grasses in this biome. These forests are very productive and play an

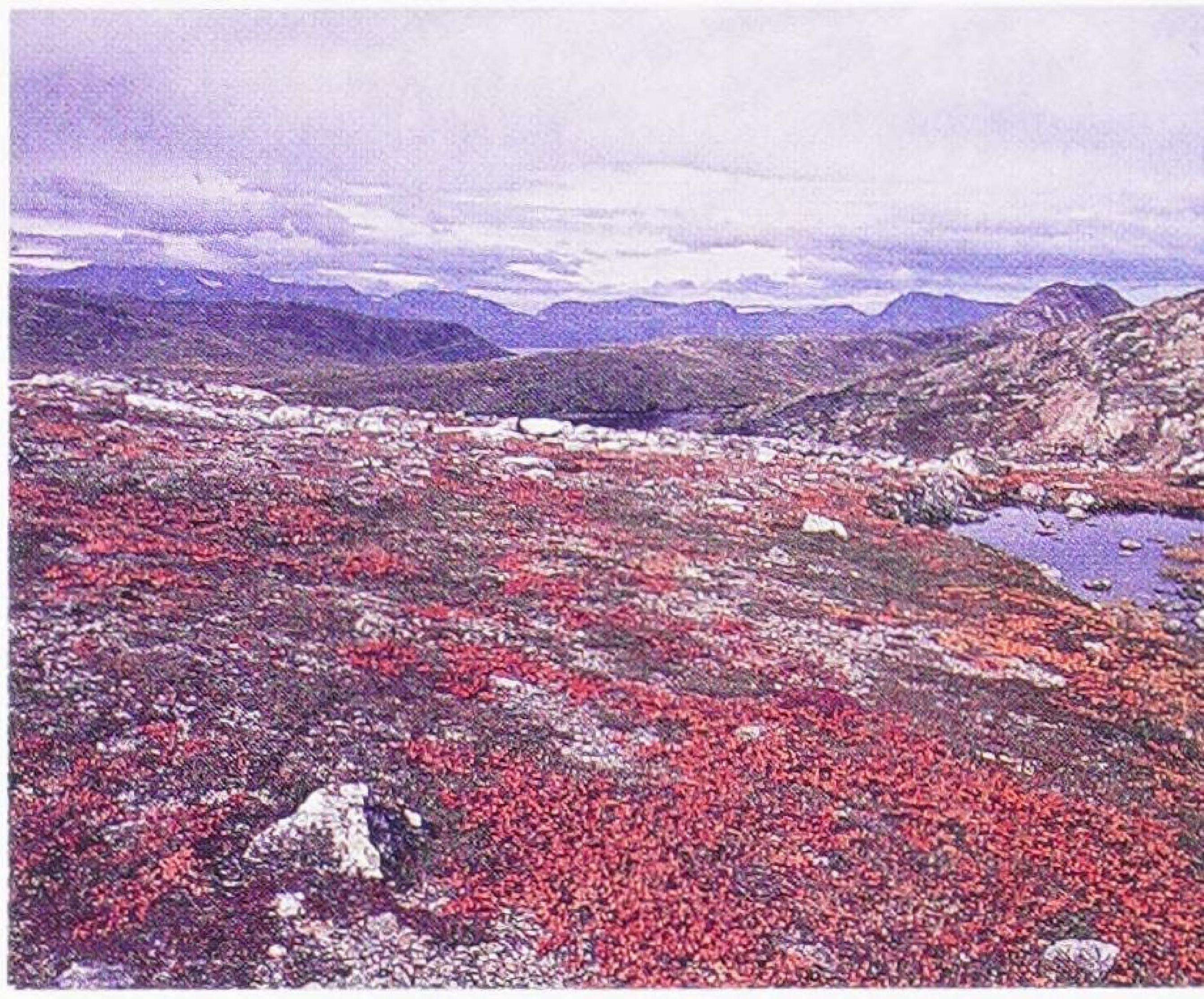


Figure 27-4. Land is so flat in the tundra that water does not drain away, and the permafrost prevents water absorption. This results in marshy conditions in the summer.

MINI-Lab

Is there tundra in Africa?

Using the land biome map on page 632, make a **hypothesis** as to whether tundra exists in Africa. Look at a globe and *compare* the latitude where tundra is found in the northern hemisphere with the same latitude in the southern hemisphere. How can you tell if your **hypothesis** is correct?

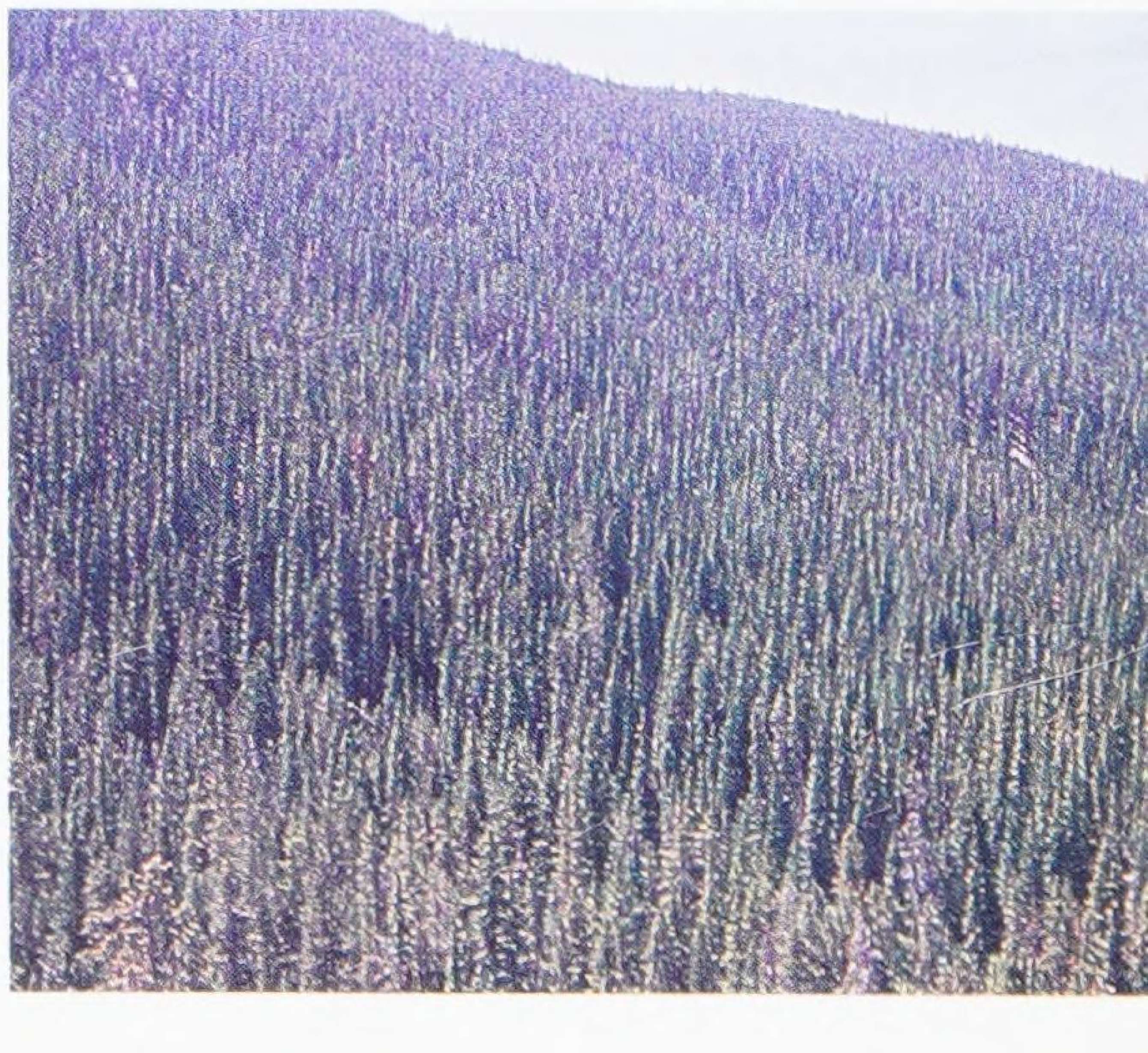


Figure 27-5. It is very dark in a coniferous forest, with deep layers of needles on the forest floor.

important role in the timber industry. Much of the lumber used for construction comes from coniferous forests.

Coniferous forest mammals, such as moose, bears, wolves, and lynx, depend on stored body fat during the cold months. Some animals migrate to warmer climates in the fall and return in the spring. Other animals hibernate six to eight months of the year.

Connect to... Chemistry

Freezing temperatures can be harmful to living things because cells are made up largely of water. As water freezes, it expands. Explain what happens to cells when freezing temperatures cause ice crystals to form in them.

Deciduous Forests

Do you live in an area where the autumn leaves change color? A *deciduous forest biome* is dominated by trees that have broad thin leaves, such as beeches, maples, oaks, hickories, sycamores, and elms. This biome has four seasons with about 75 to 150 cm of rainfall distributed evenly throughout the year. Winters are cold, summers are long and warm, springs and falls are mild. The climate and rich soil support large numbers of plant and animal species. Deciduous forests are found in the eastern United States, Europe, and parts of Asia, South America, Africa, and Australia.

White-tailed deer, foxes, raccoons, opossums, and squirrels are typical mammals that live in the North American deciduous forest. Black bears are found in some regions. Mice, snakes, and other animals are found on the forest floor. Some animals hibernate during cold winters. Others, including many bird species, migrate to warmer climates for the winter.

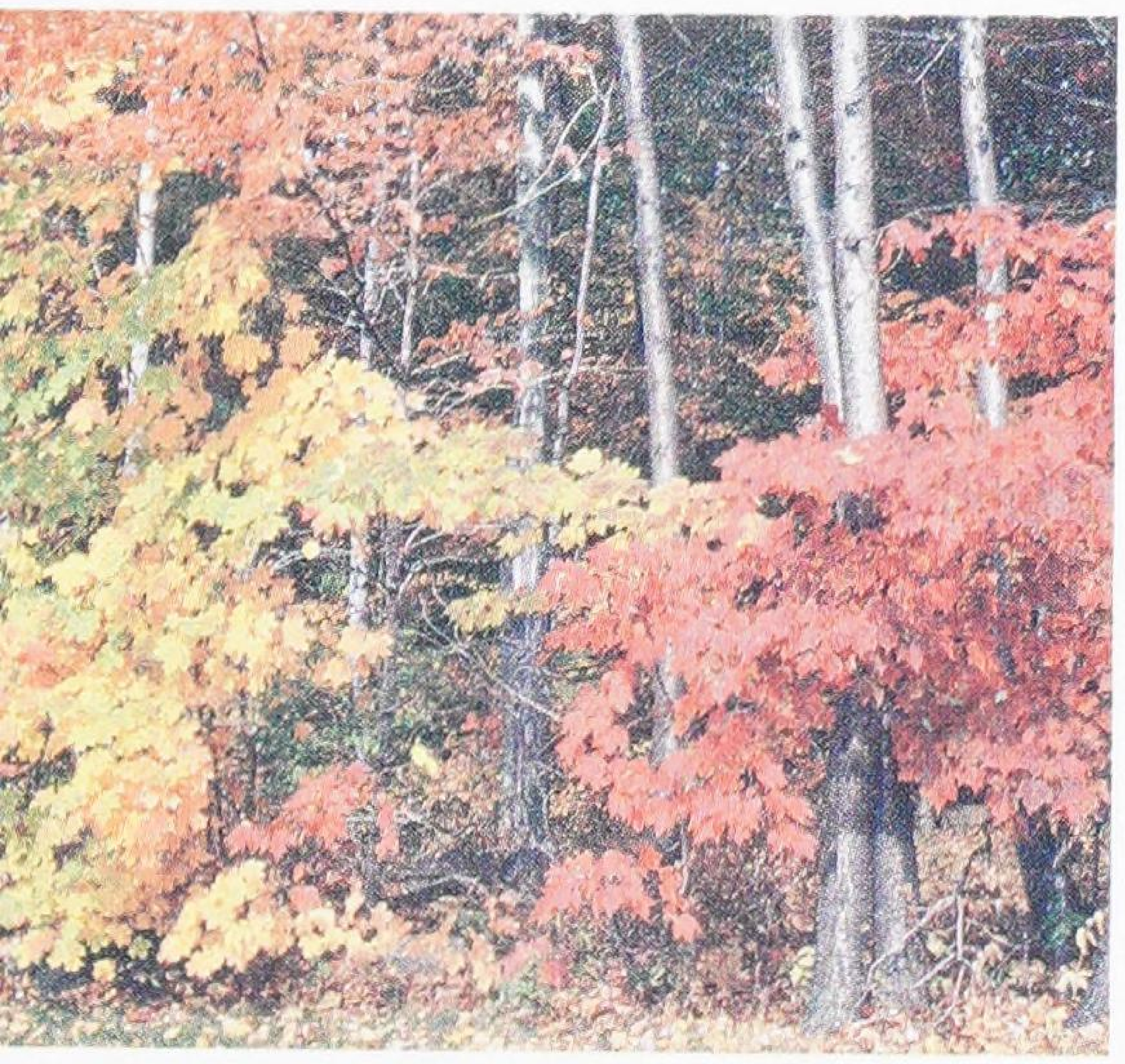


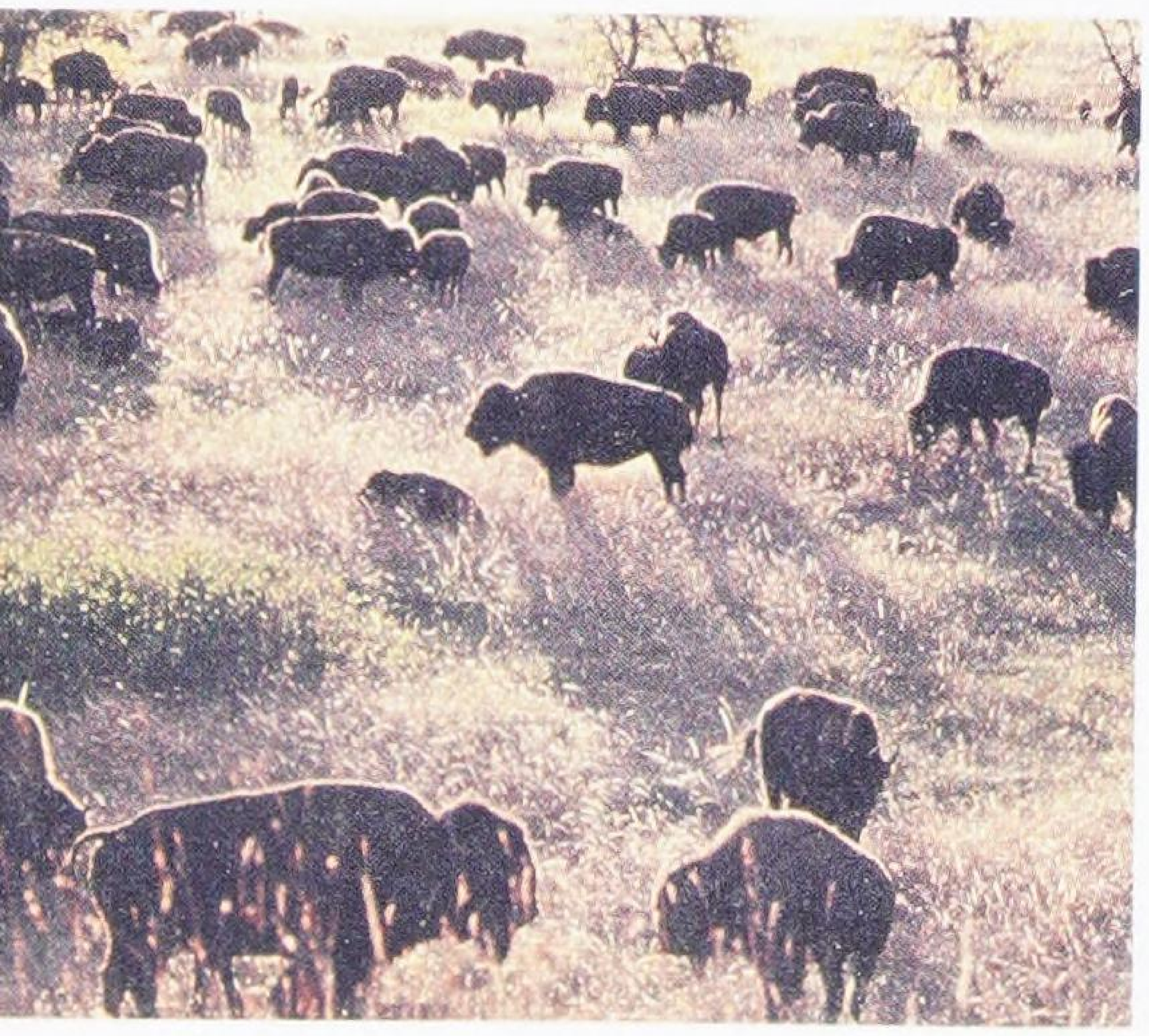
Figure 27-6. Deciduous forests like this once covered all of Europe and the eastern United States.

Grasslands

About one-fourth of the land surface on Earth is covered by grassland biomes. The *grassland biome* is dominated by grasses. These biomes occur at about the same latitude as deciduous forests, but they do not receive enough precipitation to support trees. Rainfall in grasslands may be only 25 to 75 cm per year. Temperatures range from very hot in the summer to below freezing in the winter. Grasslands are called prairies in North America, pampas in South America, savannas or veldts in Africa, and steppes in Asia.

Many grasslands are subject to periodic fires. Grasses in these biomes have roots that can send out shoots to form new plants. Extensive root systems absorb water over large areas when it rains.

Figure 27-7. Grasslands may be very hot in the summer and very cold in the winter. Grassland species are adapted to these variations in temperatures.



Some grasslands support large numbers of grazing animals. The grazing mammals in North America include bison and antelope. Zebras, wildebeasts, and giraffes are found in Africa, and kangaroos graze in Australia.

Grasslands are very important to humans. Most of the grains used for human food, such as wheat and rye, are grown in grassland areas.

Deserts

What is a desert biome?

A *desert biome* receives less than 25 cm of rainfall a year and has a high rate of evaporation. Most deserts have little cloud cover to hold the heat, so it is quickly lost once the sun goes down. The temperature may drop as much as 40°C in 12 hours. This results in hot days and cold nights. In some deserts rain may not fall for more than a year, and then a huge thunderstorm may dump more than 12 cm all at once.

Figure 27-8. Many desert plants have extensive root systems to collect as much water as possible when it rains. A single saguaro cactus can store as much as 900 liters of water.

Populations of organisms that live in deserts are adapted to the climate. Whenever sufficient rain falls, annual plants grow, flower, and produce seeds in a short time. Then they remain inactive during the long dry periods. Some plants store water in their thick stems and leaves. The saguaro cacti of Arizona and Mexico store water and carry out photosynthesis in thickened stems. The leaves or stems of many plants have sharp protective spines to protect them from thirsty animals.

Desert animal populations are also adapted to their environment. Kangaroo rats, pocket mice, and gerbils get water from the seeds they eat. Some kangaroo rats store seeds in their burrows to soak up the moisture found there. Blood vessels in the large ears of jackrabbits and foxes circulate blood to cool the animals.

Tropical Rain Forests

When you think of the tropics, do you imagine a jungle? A *tropical rain forest biome* has hot, wet weather throughout the year and the greatest variety of organisms on Earth. Rainfall averages 200 to 225 cm per year. High temperatures and abundant rainfall contribute to high humidity. Three major tropical rain forests are found in South America, Africa, and Southeast Asia.

Tropical rain forests contain more than 50 percent of all species of organisms on Earth. The soil is often not

In Your JOURNAL

The International Children's rainforest in Monteverde, Costa Rica, protects more than 5000 hectares of tropical rain forest. Find out how this rain forest was protected by children from the United States, Sweden, Canada, England, and Japan. Write a report **in your Journal** to share with your class.

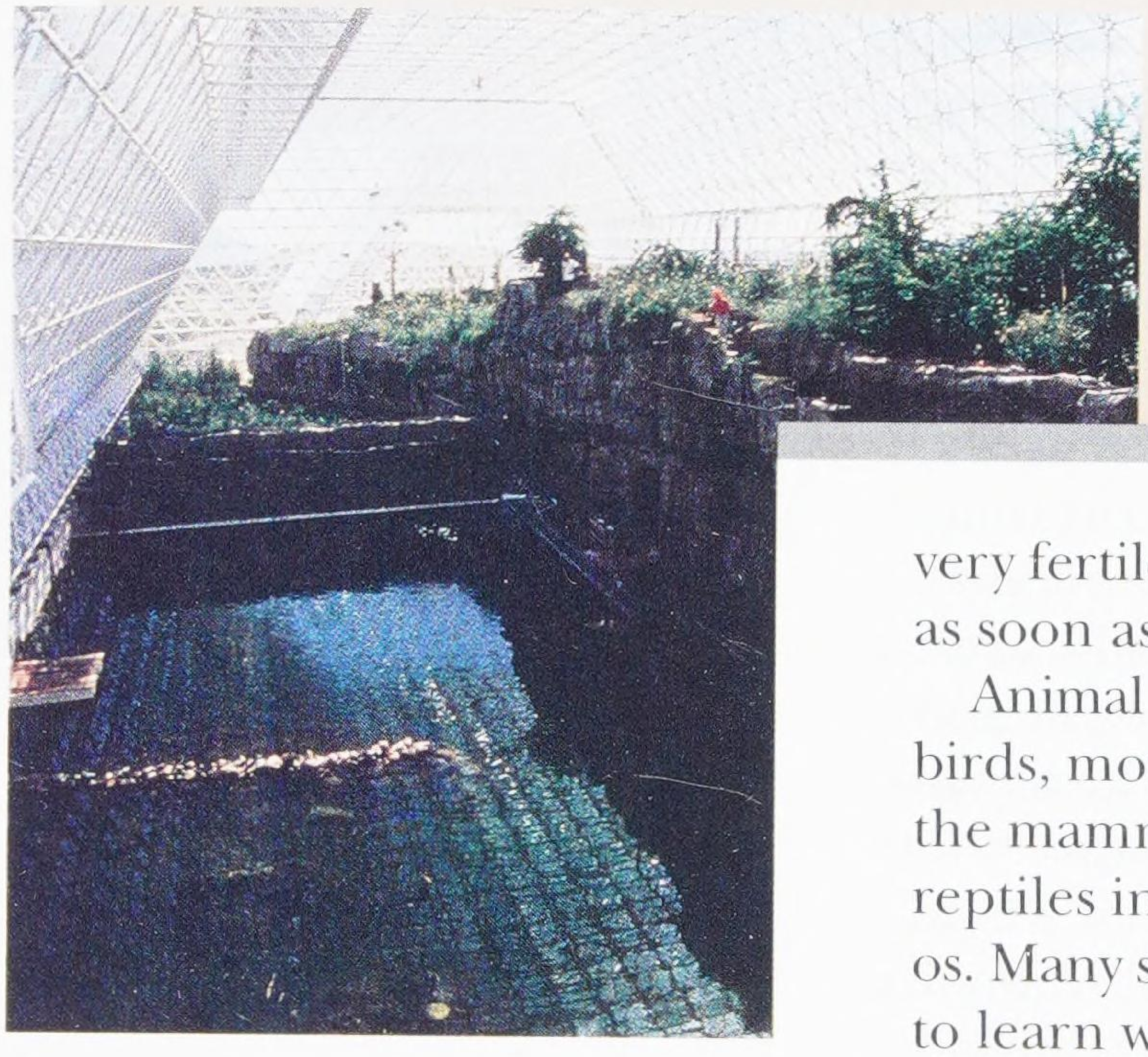
TECHNOLOGY

Life in a Glass World

Biosphere II is the name given to a unique greenhouse in Arizona that is the world's largest closed ecosystem. Eight volunteers live, work, study, and play inside Biosphere II and get all the food they need from the six biomes represented there. The biomes include an agricultural biome, a desert, a marsh, an ocean, a savanna, and a rain forest. The intensive agricultural biome has food crops, fish ponds, and domestic animals. Water in Biosphere II recycles in the rain forest, although some of the total 6.6 million liters flows into the savanna.

What can scientists learn from Biosphere II? It may help scientists better understand life on Earth, provide a model for future space colonies, and allow scientists to test some new technologies.

Think Critically: What problems do you need to solve in a closed ecosystem?



very fertile because most nutrients are taken up by plants as soon as they become available through decay.

Animal life is very diverse in the rain forest, with insects, birds, monkeys, and large cats. More than 50 percent of the mammals in rain forests live in the trees. Rain forest reptiles include chameleons, snakes, iguanas, and geckos. Many scientists are studying the remaining rain forests to learn what new organisms may be found there.

SECTION REVIEW

1. Define *biome* and list the six major biomes on Earth.
2. How do grasslands differ from coniferous forests?
3. What kinds of adaptations have desert animals made to survive without much water?
4. **Apply:** Why don't large trees grow in the tundra?
5. **Connect to Earth Science:** What determines the amount of solar energy received at a particular location on Earth?

Skill Builder

Concept Mapping

Make a concept map of plant and animal species found in each land biome. If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

Water Ecosystems

27-3

Objectives

- Distinguish between marine and freshwater ecosystems.
- Describe the zones in the ocean.
- Identify the limiting factors present in marine and freshwater ecosystems.

New Science Words

littoral zone
sublittoral zone
pelagic zone
estuary

Marine Ecosystems

If you had to name the largest biome on Earth, would you answer the ocean? The major land biomes are surrounded by the oceans. The *marine ecosystem* is a continuous body of water that covers more than 70 percent of Earth's surface.

The amount of salt present is the major limiting factor in water ecosystems. Ocean water may contain as much as 3.5 percent salt, whereas fresh water contains less than 0.005 percent salt. Other limiting factors in marine ecosystems are temperature, light, the amount of dissolved oxygen, and water pressure. Light and temperature decrease as the depth of the water increases, but water pressure increases with depth.

Figure 27-9 shows the major zones of the ocean. The zone along the shore is the **littoral** (LIHT uh rul) **zone.** During high tide it is covered with water, and during low tide it is exposed to the air. Populations living in the littoral zone are adapted to the wet and dry conditions and to the force of the waves hitting the shore. Sea stars, sea anemones, and mussels cling to rocks. At low tide, mussels close their shells and crabs burrow into the moist sand to keep from drying out. The organisms that live there have to be able to withstand varying temperatures, water levels, and salt levels.

The part of the ocean floor that slopes downward is the continental shelf. The shallow water above the continental shelf is called the **sublittoral zone.** This zone has enough light and nutrients to support a wide variety of

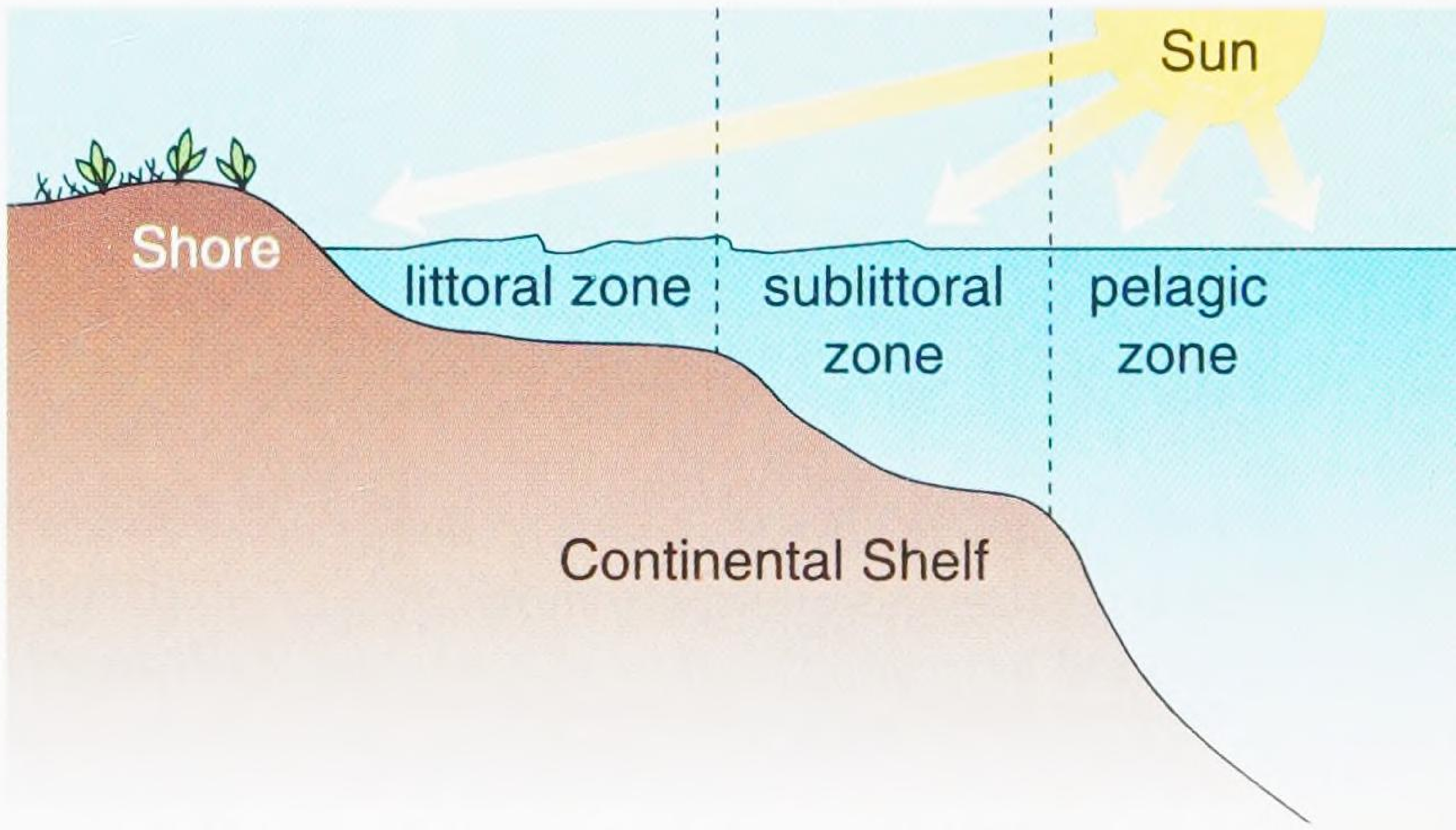


Figure 27-9. Most marine life is found in the littoral and sublittoral zones of the ocean where sunlight penetrates.

Figure 27-10. Organisms that live in the littoral zone are adapted to both wet and dry conditions.

organisms. Most life in the ocean is found in the littoral and sublittoral zones. Microscopic organisms that float or swim near the surface of the water include protozoans,algae, and invertebrates. Shrimp, oysters, and fish all feed on these organisms and are eaten in turn by other fish, squid, some whales, walruses, and seals.

The open ocean just beyond the sublittoral zone is the **pelagic zone.** Sunlight filters down to a depth of about 200 meters. Below 200 meters this zone is dark and cold. Water pressure is extremely high. Some animals living here move up to feed, and others eat dead organisms that filter down from the water above.

Figure 27-11. Most marine fish caught for food or sport were hatched in estuaries like this.

The area where a freshwater river or stream meets the ocean is called an **estuary.** Salt marshes, deltas, and mud flats may all be estuaries. The water is shallow in estuaries, allowing light to penetrate to the bottom. Rivers bring nutrients washed from the land to algae, marsh grasses, and other plants growing along the shore. The continuous mixing of fresh water with ocean water keeps nutrients in the estuary and removes wastes from it. Oysters, clams, mussels, and snails are abundant. Estuaries serve as breeding grounds for many marine organisms such as fish, arthropods, and mollusks. Shore birds nest and raise their young in estuaries because of abundant food resources.

Connect to...

Physics

Find out why organisms in the oceans use less energy in moving around than you do.

Freshwater Ecosystems

What is a freshwater ecosystem?

Most of you probably are familiar with a freshwater ecosystem like the one in Figure 27-12. *Freshwater ecosystems* include lakes, ponds, streams, rivers, swamps, and bogs.

The types of organisms found in freshwater ecosystems depend largely on temperature, current, and the amounts of oxygen and minerals dissolved in the water.

Water temperature in freshwater ecosystems does not vary as much as the temperature of air. As a result, populations that live in water are adapted to a narrow temperature range, and many cannot survive freezing or extreme heat. The primary limiting factor in freshwater ecosystems is the amount of oxygen dissolved in the water. A fast-moving stream has more oxygen in it than a stagnant pond. Cold water can hold more oxygen, yet there may be fewer organisms in cold water because temperature is also a limiting factor.

Figure 27-12. Fast-moving water like this contains far fewer organisms than slow-moving streams.

Lakes and ponds are classified according to the amount of organic matter. Those that are rich in organic matter

PROBLEM SOLVING

What Caused the Fish to Die?

Fish breathe by allowing water to flow over the many blood vessels in their gills. As the water passes over the blood vessels, oxygen from the water is absorbed and carbon dioxide is released.

Recently, several hundred thousand fish and other marine creatures were killed along the Gulf Coast because there was not enough oxygen in the water. Unfavorable weather conditions caused the problem. After several days of high heat and calm water, the oxygen content of the water decreased to a level that could not sustain wildlife. As the water warmed up, it lost its ability to hold oxygen. The calm water also contributed to the low oxygen levels. Turbulent water traps air bubbles, and gases from the air dissolve in the water. What caused the fish to die?

Think Critically: Why do aquariums use air pumps to bubble air through the water?

usually have cloudy or green waters. Those that contain little organic matter have water that is clearer, is blue in color, and has a sandy or rocky bottom. Which type of pond has more nutrients? Ponds with lots of organic matter have more nutrients and can support more species.

EcoTip

Boat engines may leak oil into estuary waters. Make sure boat engines are in good working order before you anchor near an estuary.

SECTION REVIEW

1. What is the main difference between marine and freshwater biomes?
2. What are the most important limiting factors in marine ecosystems? In freshwater ecosystems?
3. Name and describe the zones in the ocean.
4. **Apply:** Developers often fill in estuaries to build homes on the shoreline. Why should this concern you?
5. **Connect to Physics:** Find out why you feel lighter in the ocean than in fresh water.

Skill Builder

Hypothesizing

Hypothesize why some fish that live in the pelagic zone of the ocean have no eyes. If you need help, refer to Hypothesizing in the **Skill Handbook** on page 686.

SCIENCE & SOCIETY

27-4 Coastal Wetlands

New Science Words

wetland
water table

Objectives

- List several important roles of wetlands in the environment.
- Name several different types of wetlands.

In Your JOURNAL

Wetlands are interesting and exciting places to visit. **In your Journal,** write a travel brochure advertising a tour of a wetland. Describe what persons will see on the tour. You may wish to illustrate the brochure with drawings.

Wetlands or Wastelands?

Have you ever traveled along a coastline and noticed large wet areas? Many of us think of these areas as being useless, unattractive breeding grounds for mosquitoes. This type of area is known as a wetland. A **wetland** is an area of land that, for at least part of the year, is covered by shallow water. There are many different types of wetlands, including coastal marshes, swamps, and bogs.

Wetlands are unique systems that are home to many species of animals and plants. Snakes, fish, turtles, snails, insects, beavers, raccoons, and a wide variety of insects are often found in wetlands. They are all dependent on the many wetland plants for both food and shelter. Wetlands also provide a resting and feeding place for birds migrating during the fall and spring, and for shore birds all year.

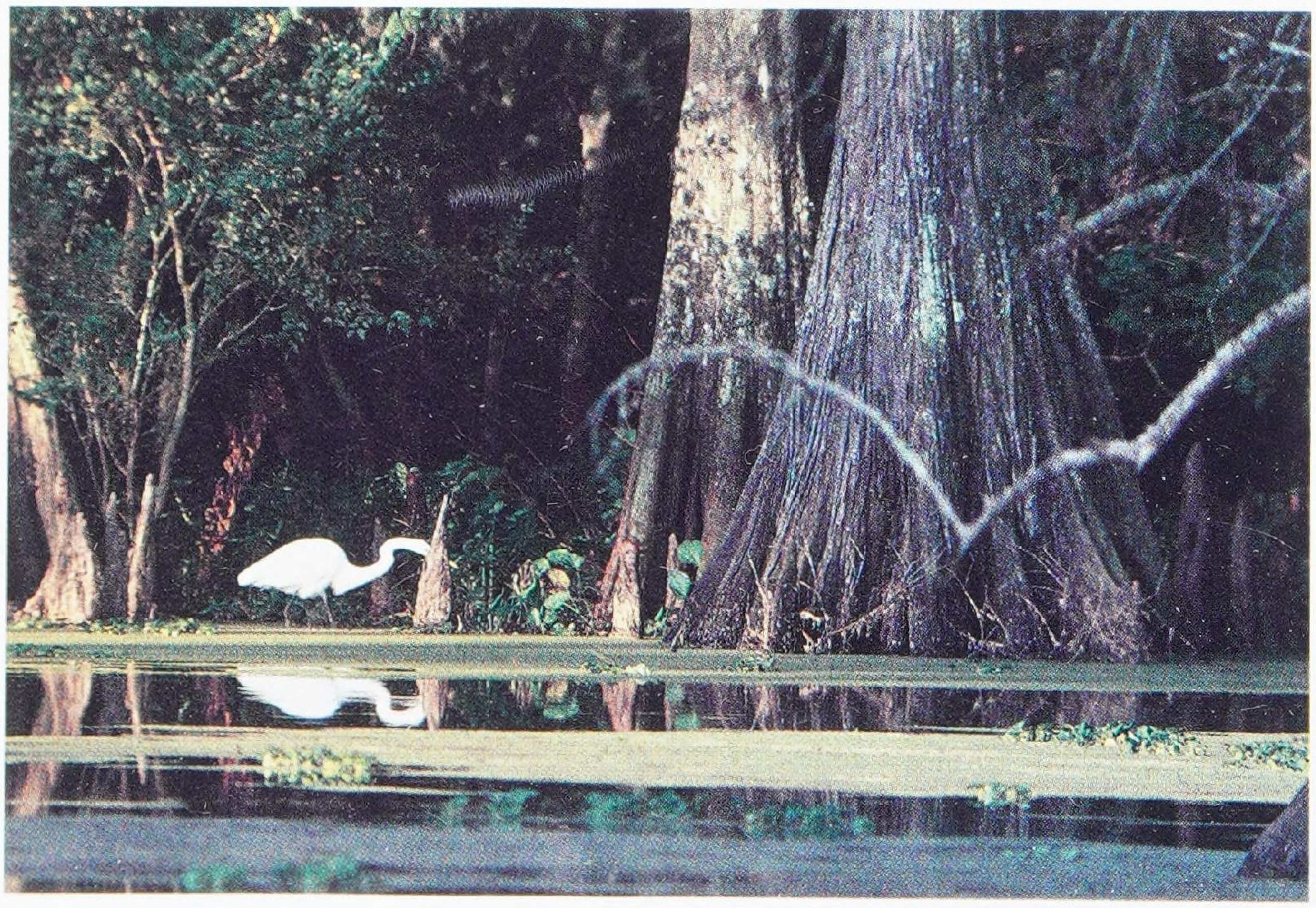
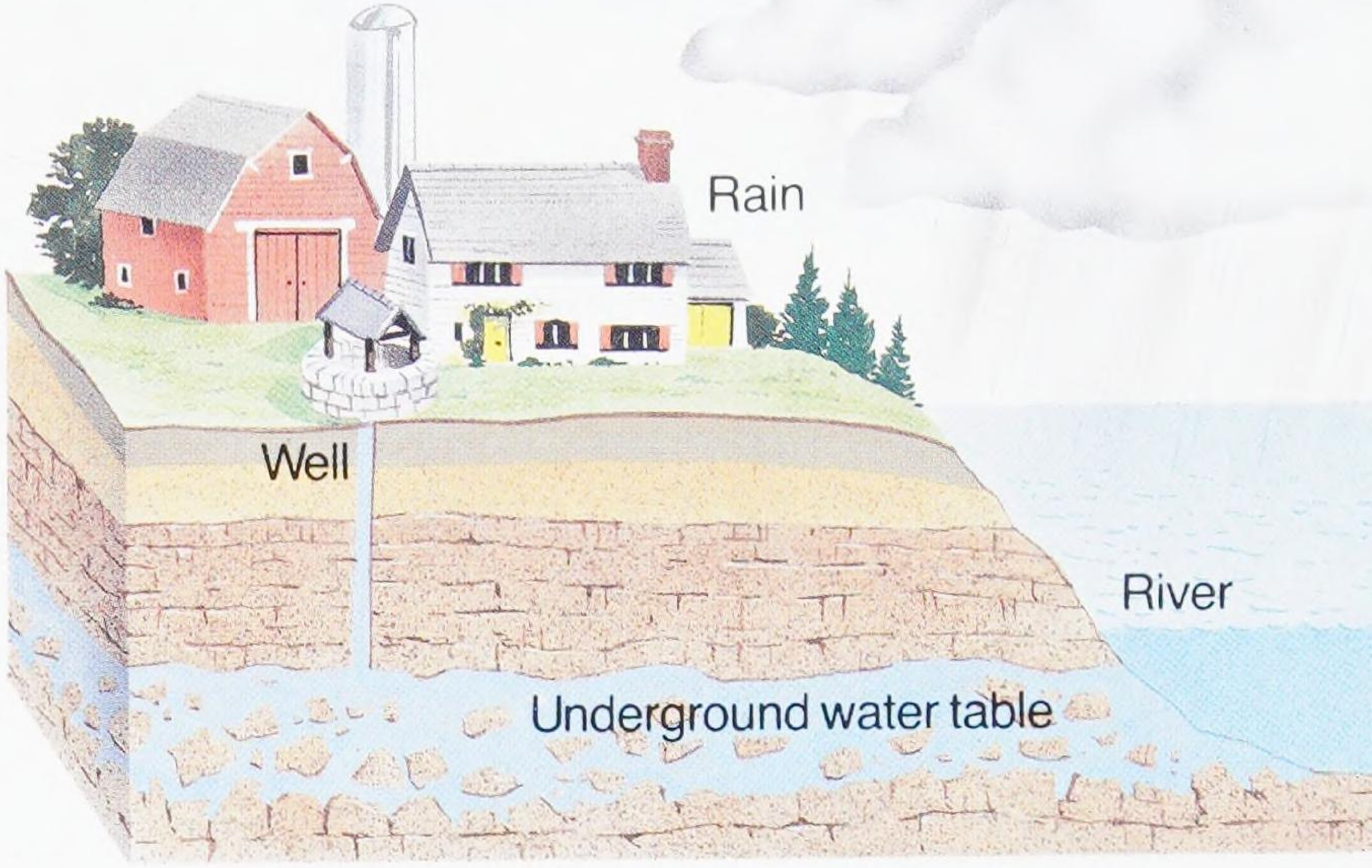


Figure 27-13. Wetlands may include estuaries, where fresh water mixes with salt water, or freshwater ecosystems.

Wetlands that are located along the coast are very important in providing food and jobs. Ninety percent of the fish harvested each year in the United States spent at least part of their lives in coastal marshes. People who live near these wetlands rely on the fishing industry for jobs. In addition, the vast coastal marshes serve as protection against storms and floods. If not protected from the rough open waters of the ocean, both coastal cities and rural areas might suffer great damage from high water and the powerful force of the waves.

Wetlands also serve as filters to clean surface water before it enters the water table. The **water table** is the underground water supply most humans rely upon for drinking water. When it rains, the rainwater soaks into the ground until it reaches the water table. But rain also washes pollutants into surface water such as streams. Where streams empty into the ocean, coastal wetland plants and soil absorb these pollutants, preventing them from moving into the ocean itself.



With the increasing need to build more homes, factories, schools, stores, and parking lots, land developers often choose wetland areas to develop because they appear to serve no practical use. To most people, wetlands seem useless. In the United States alone, millions of hectares of wetlands have already been drained for development. Many species of plants and animals are now endangered due to the loss of this wetland habitat.

Environmentalists are working with local governments to develop solutions. All over the country, wetland protection plans are being developed to preserve the remaining wetlands. However, as the population continues to grow, there is continuing pressure to develop wetlands. A balanced development of coastal areas may require compromise on both sides of the wetlands debate.

Did You Know?

In southern Florida, increased human population has resulted in loss of 60 percent of the original wetlands. Ninety-five percent of the wading birds in the Everglades have disappeared.

SECTION REVIEW

1. What are two important roles of wetlands?
2. **Connect to Chemistry:** Find out the salt content of the water in a coastal wetland. Does it vary? If so, when and why?

SCIENCE & SOCIETY

You Decide!

In some states, developers are required to build a new wetland for any that they might destroy during development. However, recent research shows that such recreated wetlands are no replacement for the natural wetlands that required years and years for nature to build. Should developers be allowed to drain wetlands for any purpose?

DESIGNING AN EXPERIMENT

ACTIVITY 27–2

Investigating a Limiting Factor

Have you ever been responsible for taking care of a plant or a pet? What happens if you forget to water and feed the plant or animal? You know from this chapter that a limiting factor is a condition that determines the survival of an organism, a population, or species in its environment. In this investigation, you will be the scientist and investigate how water can be a limiting factor in the germination of bean seeds.

Getting Started

In preparation for designing your experiment, answer the following questions:

1. What question are you investigating?
2. Why is water important to all living things?
3. What variables are important in this experiment?

Hypothesis

What is your **hypothesis?** What is the reasoning behind your hypothesis? Share this information with your group. Choose the best idea that could be investigated in the classroom.

Brainstorm

As a group, make a list of possible ways to test your hypothesis.

Experimental Plan

- **Design an experiment** to test one variable. Make sure you plan to collect quantitative data.
- In a numbered list, similar to a recipe, make a set of directions that anyone can follow to do the experiment.
- Make a list of materials and the quantities needed to do the experiment.

Answer the Following Questions

1. Have you included a control? Explain.
2. What will you measure?
3. How many seeds will you test?
4. Develop a data table and write in your data as you collect it.

Make sure your teacher has approved your experimental plan before you go further.

Data and Observations

1. Carry out your experiment. Make a table of your data.
2. Make a line graph of the data you recorded in the data table.

Data Analysis and Interpretation

1. Was your **hypothesis** supported by your data? Explain.
2. What were the sources of error in your experiment?
3. If your hypothesis was not supported, what can you conclude?
4. What did you determine bean seeds need to germinate?
5. How does this experiment *relate* to what you are studying in class?
6. Write a brief conclusion based on your data.

Going Further

Based on your data and observations, design another experiment that would help to expand your conclusions or answer a question that came up as you conducted your experiment. Your teacher will tell you whether you will conduct this experiment in class or whether you can design your experiment based on having unlimited resources.

CHAPTER REVIEW

SUMMARY

27-1: Factors That Affect Biomes

1. Limiting factors such as water, sunlight, and temperature determine the survival of organisms, populations, and species in the environment.

2. Over time, communities change in an orderly process called succession. Succession results in a balanced ecosystem called a climax community.

3. Primary succession occurs on new land, whereas secondary succession returns disturbed areas to a more stable climax community.

27-2: Land Biomes

1. Biomes are large geographic areas with similar climates and climax communities.

2. Land biomes include tundra, coniferous and deciduous forests, grasslands, deserts, and tropical rain forests.

3. Biomes share climate conditions, but the specific organisms found in each may differ.

27-3: Water Ecosystems

1. Marine ecosystems and freshwater ecosystems differ in the organisms that live there. This is due to the amount of salt present in the water.

2. Marine organisms have adapted to a salty environment and live in different ocean zones.

3. Freshwater organisms have adapted to life in still or moving water.

27-4: Science and Society: Coastal Wetlands

1. Wetlands are home to unique organisms, serve as nesting and feeding sites for many different animal species, and filter pollutants from surface waters.

2. Wetlands include coastal marshes, swamps, and bogs.

KEY SCIENCE WORDS

a. **biomes**
b. **climate**
c. **climax community**
d. **estuary**
e. **limiting factor**
f. **littoral zone**
g. **pelagic zone**
h. **permafrost**
i. **primary succession**
j. **secondary succession**
k. **sublittoral zone**
l. **succession**
m. **tundra**
n. **water table**
o. **wetland**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. a condition that determines the survival of an organism
2. area where fresh water and salt water mix
3. underground water supply
4. frozen soil of the tundra
5. shallow water above the continental shelf
6. gradual change in a community over time
7. a stable, balanced community
8. ocean zone along the shore
9. areas of similar climate and communities
10. an area of land covered by water

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. The climate of an area is determined by _______.
   a. limiting factors c. biotic factors
   b. succession d. abiotic factors
2. _______ return(s) a burned forest to its previous condition.
   a. Secondary succession
   b. Limiting factors
   c. Primary succession
   d. A climax community
3. The _______ is a treeless, cold biome.
   a. grassland c. tundra
   b. desert d. permafrost
4. All are examples of grasslands except _______.
   a. pampas c. savannas
   b. steppes d. estuaries
5. Swamps, bogs, and marshes are examples of _______.
   a. grasslands c. coniferous forests
   b. deserts d. wetlands
6. Oysters and clams have adapted to the mild waters of the _______.
   a. pelagic zone c. estuary
   b. sublittoral zone d. littoral zone
7. Limiting factors in water ecosystems include _______.
   a. current c. dissolved oxygen
   b. temperature d. rainfall
8. The _______ has the most variety of organisms of any biome.
   a. desert c. tropical rain forest
   b. tundra d. deciduous forest
9. A(n) _______ is the end result of succession.
   a. wetland c. climax community
   b. limiting factor d. estuary
10. Trees are parts of the communities of each biome except_______.
    a. deciduous forest c. tropical rain forest
    b. tundra d. coniferous forest

USING LAB SKILLS

11. In Activity 27-1 on page 630 you interpreted a hardiness zone map and learned that organisms live only in certain areas. What might be the effect on today's growing areas if all climates became warmer?
12. In the MINI-Lab on page 631 you studied how communities change. Obtain a jar of pond water and observe it over a period of several weeks. Cover the jar and place it in an area where it will receive light. Use a microscope to observe water from the jar twice each week. Record the changes you observe.

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Compare primary and secondary succession.
14. What is the difference between coastal wetlands and the littoral zones of marine ecosystems?
15. Why are soils in rain forests not very fertile?

APPLY

16. Why do mammals of the coniferous forest hibernate?
17. How does climate help determine what species live in communities?

18. What special adaptations might plants and animals that live in fast-moving water have?

19. Northern coniferous forests are climax communities. Why don't they change through succession to oak-hickory forests?

20. Make a food chain that could be found in a deciduous forest.

MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. Comparing and Contrasting: Make a chart to compare and contrast these biomes.

Biome	Weather	Plants	Animals
Tundra			
Grasslands			
Deserts			
Tropical Rain Forests			

2. Concept Mapping: Make a concept map for water ecosystems. Include these terms: *marine ecosystems, freshwater ecosystems, littoral zone, pelagic zone, sublittoral zone, lake, pond, river, stream.*

3. Making and Using Graphs: Make a bar graph of the amount of rainfall per year in each biome.

Biome	Rainfall/Year
Deciduous forests	100 cm
Tropical rain forests	225 cm
Grasslands	50 cm
Deserts	20 cm

4. Comparing and Contrasting: Make a chart to compare and contrast the plants and animals of the northern coniferous forests and deciduous forests.

5. Interpreting Data: Interpret the data given and decide which area of a stream has more varieties of living things and explain why.

Organism	Number in Pools	Number in Riffles
Midgefly larva	0	1000
Caddisfly larva	2	70
Snail	2	12
Water penny	1	7
Mayfly larva	1	250
Stonefly larva	1	61
Horsefly larva	1	8
Water strider	8	1
Dragonfly larva	2	7
Water diving beetle	3	1
Whirligig beetle	5	2

A riffle is a small wave. Find the total number of organisms in each area.

PROJECTS

1. Do you have relatives, friends, or a pen pal who lives in a different biome than you do? Each of you can make a list of common plants and animals in your biome and exchange the lists.
2. Research the Atacama Desert of Chile. Find out how much rainfall the desert receives in one year. Report to the class on your findings.
3. Find out where the grains that humans depend on for food originated, and in what type of biome. Include grains such as corn, wheat, rice, barley, rye, and sorghum in your answer.

CHAPTER

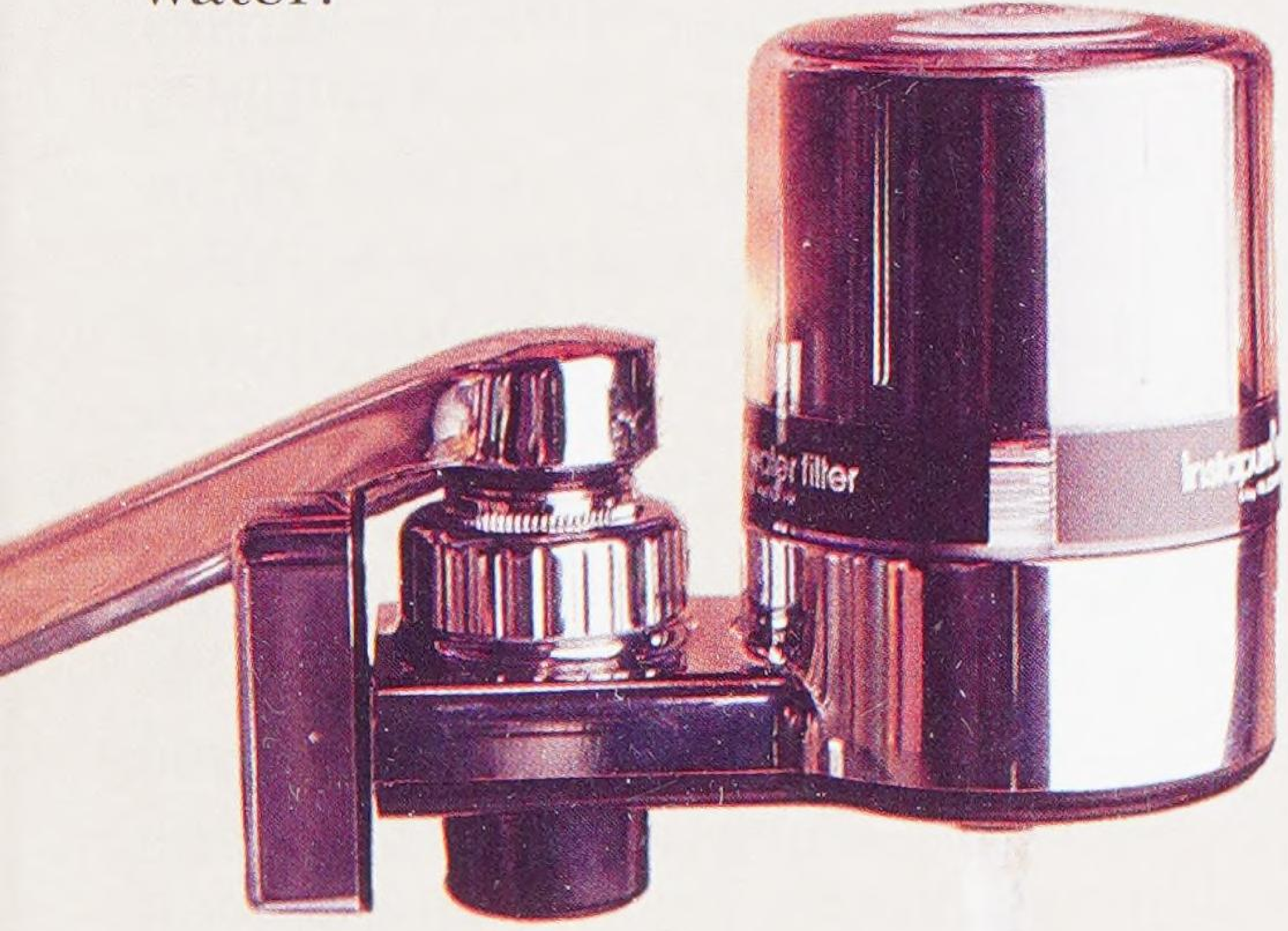
28 Resources and the Environment

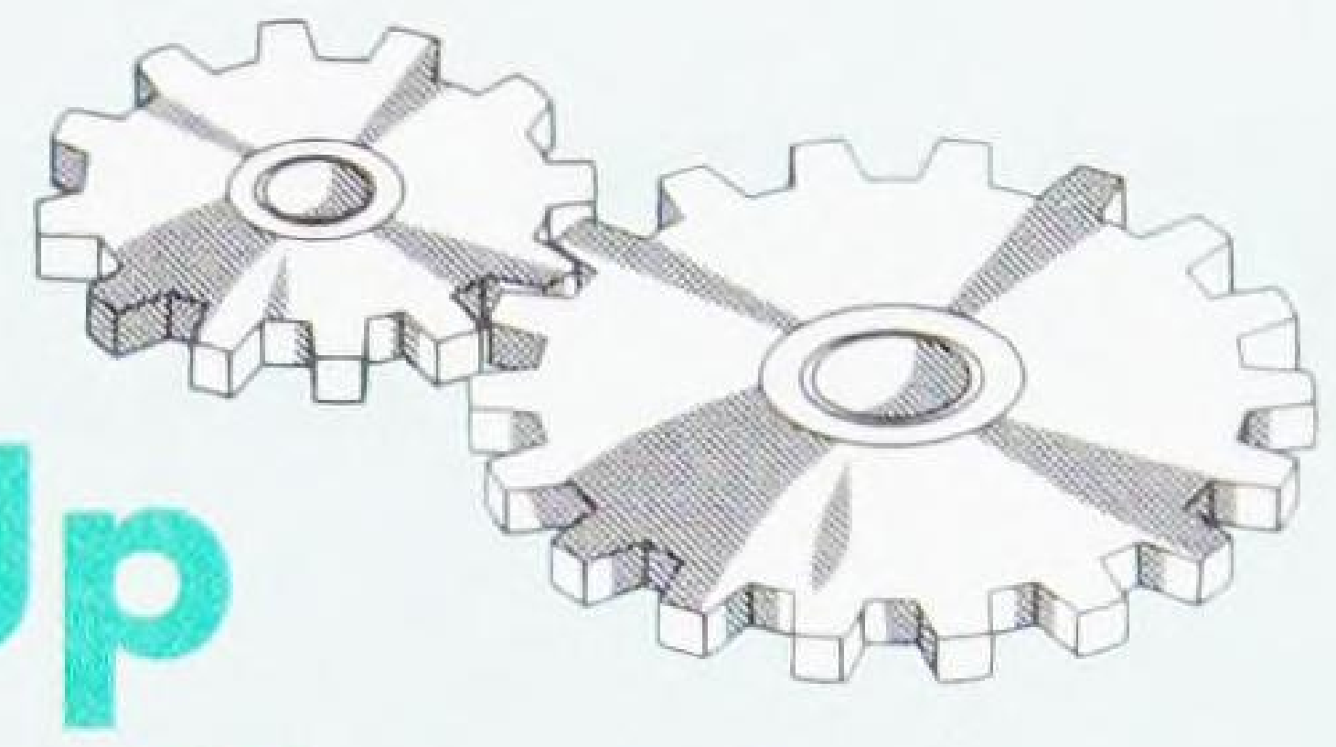
Water is essential for all life on Earth. You know that the water used for washing dishes will go down the drain. But then where does it go? Water may go into a sewer system and enter a water treatment plant. How does today's wastewater become tomorrow's clean water? How is water cleaned so it can be used again?

FIND OUT!

Do this simple activity to find out how water can be cleaned.

Stir some garden soil and plant material into a beaker filled with water. When the water looks muddy, pour most of it through a coffee filter into a bowl. *Compare* the water in the beaker with the water in the bowl. Filters can remove some kinds of wastes from water, but do they remove all wastes? How would you remove other wastes from the filtered water?





Gearing Up

Previewing the Chapter

Use this outline to help you focus on important ideas in this chapter.

Section 28-1 Natural Resources
- What Are Natural Resources?
- Resources Are Limited

Section 28-2 Conservation and Protection
- What Is Conservation?
- Cleaning Up the Air
- Cleaning Up the Water
- Waste Disposal
- Protecting Soil and Forest Resources
- Protecting Wildlife

Section 28-3 Future Responsibility
- Environmental Management
- Individual Responsibility

Section 28-4 Science and Society
Earth in 2030
- The Future: Grand or Grim?

Previewing Science Skills

- In the **Skill Builders,** you will hypothesize, make concept maps, and recognize cause and effect.
- In the **Activities,** you will hypothesize, experiment, and analyze.
- In the **MINI-Labs,** you will survey, organize information, collect data, interpret data, and record.

What's next?

Now you know that wastewater can be partially cleaned by filtering. In this chapter, you'll learn about the impact humans have on natural resources and how you can help conserve these resources.

28-1 Natural Resources

New Science Words

natural resources
renewable resources
nonrenewable resources
greenhouse effect
solid wastes
erosion

Objectives

- Identify natural resources and describe how they are important to living organisms.
- Distinguish between renewable and nonrenewable resources and give three examples of each.
- Describe how resources are affected by human use.

What Are Natural Resources?

Mountain gorillas live in family groups high in the mountains of Rwanda and Uganda in Africa. They eat fruits and leaves and drink water from clear mountain streams. At night, these gorillas bend branches of trees down to make nests to sleep on. How do you get ready for bed? You brush your teeth with a plastic toothbrush, take a drink of water, then slip between cotton sheets on your bed. Do you have anything in common with mountain gorillas? Both humans and gorillas rely on natural resources in their environment. **Natural resources** are the raw materials in the environment that organisms use for survival. Natural resources include biotic and abiotic materials such as water, soil, air, forests, wildlife, and minerals that organisms use in their daily lives. The food you eat, the clothes you wear, and the roof over your head all are necessary for your survival, and all came from natural resources.

What are natural resources?

The cotton used to make your sheets is a renewable resource. **Renewable resources** are those natural resources that can be replaced by nature over a period of time. Trees, wildlife, and soil are renewable resources. Cotton for sheets is a renewable resource because cotton plants can be planted every year. Air, water, and sunlight are renewable resources that all life depends upon.

Nonrenewable resources are those natural resources that are available only in limited amounts and cannot be replaced by nature. Many of the products you depend on every day are made from nonrenewable resources. Plastic toothbrushes, polystyrene cups, and gasoline all are made from petroleum, a fossil fuel. Fossil fuels are fuels made up of organisms that lived and died millions of years ago.

Figure 28-1. Nonrenewable resources such as petroleum are available only in limited amounts.

Petroleum, coal, peat, and natural gas are fossil fuels. Some minerals that are recycled very slowly, such as phosphorus, are also called nonrenewable resources.

Resources Are Limited

Have you ever rushed to the music store to buy a tape advertised in the paper, only to find the store is sold out when you arrive? If you looked at the advertisement carefully, you might see the words, “Supplies are limited.” Supplies of natural resources on Earth are limited, too. Natural resources on Earth are not distributed evenly. You already know from Chapter 27 that deserts are biomes with very few natural resources. Today, many of Earth’s natural resources are being damaged as a result of human activities. Air pollution, water pollution, and the problem of solid waste disposal are daily headlines. Soil, forests, and wildlife are natural resources in danger because of human actions. These problems are discussed in the following sections.

Connect to...
Chemistry

In addition to carbon dioxide, water vapor, methane, nitrous oxide, and chlorofluorocarbons (CFCs) increase the greenhouse effect. CFCs are compounds that are used as coolants, solvents, and propellants in aerosol cans. How do CFCs affect the environment?

Air Pollution

Air pollution occurs when the air is polluted by gases from vehicles or power plants that burn fossil fuels. Air can be polluted by carbon monoxide, nitrogen oxide, sulfur dioxide, hydrocarbons, and by tiny particles of ash, lead, dust, or soot. Some air pollution occurs naturally, for example, when gases are released from a volcano. Most air pollution results from the burning of fossil fuels in power plants and in automobiles. The burning of coal to produce electricity releases tons of sulfur dioxide into the air each year in the United States. Sulfur dioxide and nitrogen oxide combine with water vapor in the air to produce acid rain.

Air pollution can also be caused by the burning of forests and grasslands. In Brazil, Indonesia, and India, farmers often clear land in this way. This burning also releases carbon dioxide into the atmosphere. Carbon dioxide and other gases form a layer around Earth that acts like a wall of windows in a greenhouse. The gases allow sunlight to pass through and warm Earth’s surface. Heat and reflected sunlight radiate back into this gas layer and are trapped there, as shown in Figure 28-2. Scientists have found evidence that the **greenhouse effect** may be causing a rise in Earth’s temperature.

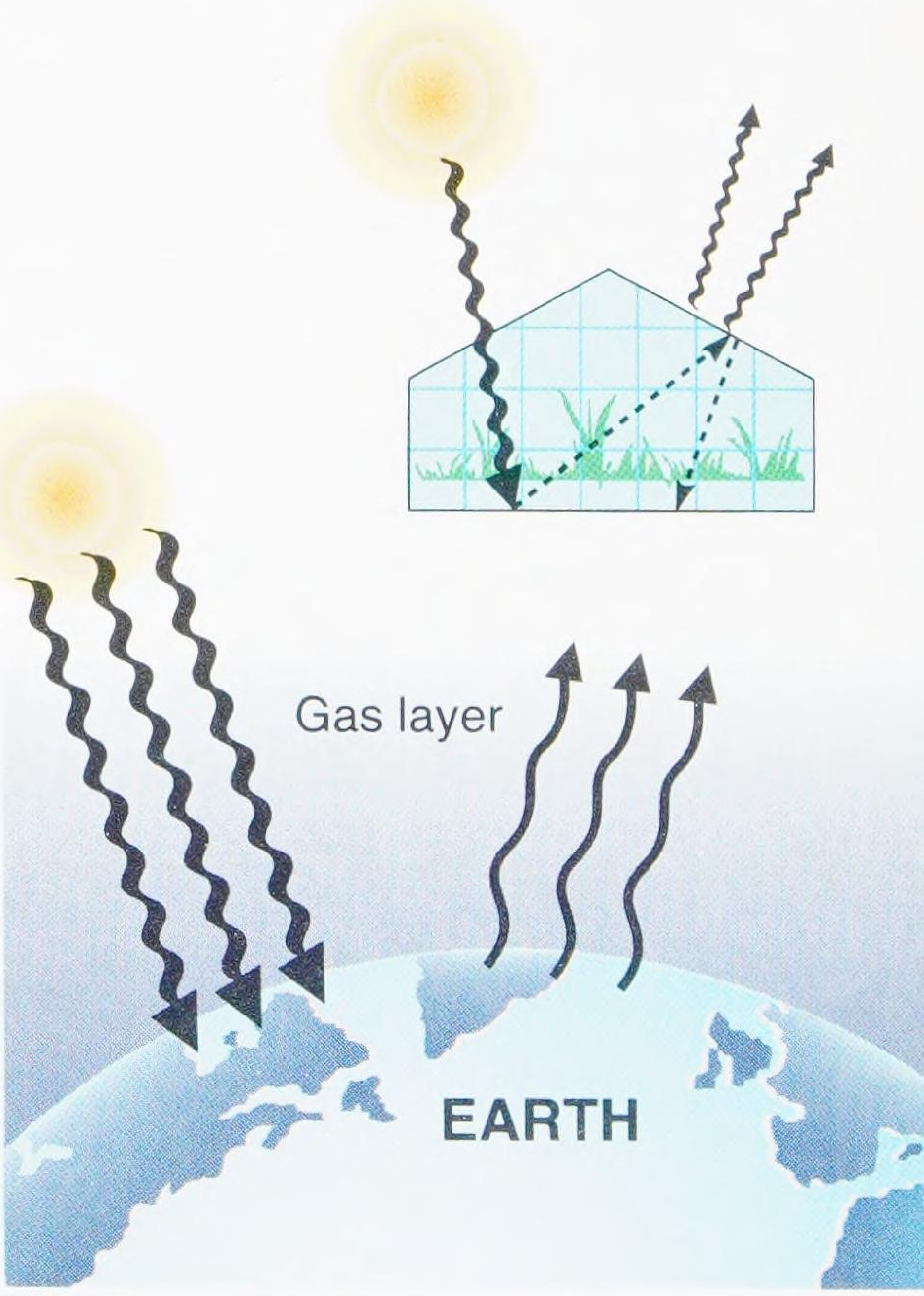


Figure 28-2. The greenhouse effect occurs when large amounts of carbon dioxide and other gases trap heat near the surface of Earth.

PROBLEM SOLVING

Sharing a Technology

Depending on where you live in the world, you may not think twice about planting a garden. Surely, there will be enough water.

But in many areas of the world, very little rain falls to make plants grow.

Israel is located in an arid part of the world. To supply plants with needed water, the Israelis have developed drip irrigation. Water from a well travels in pipes to thin drip lines that lie along plant rows, then drips out through small holes. Plants receive water throughout their growth period.

Similar dry conditions existed on the Navajo Reservation in Arizona. In 1984, the Navajos asked the Israelis to share their irrigation technology. As a result, Navajo farms now produce a bountiful variety of fruits and vegetables.

Think Critically: Why would continuous drip irrigation be better for roots than flooding the fields when they get dry?

MINI-Lab

How much garbage do you produce?

Ask your family to help you collect everything that is thrown away in your household in one week. Collect garbage in paper or plastic bags. At the end of the week, carefully weigh each bag. Add the weights to find the total amount of garbage, then divide by the number of people in your household. *Interpret* your data to find out how much garbage you produce in one week.

Water Pollution

In many places on Earth, water is the most scarce resource. Most of the water on Earth is in the oceans or locked in polar ice caps. Fresh water accounts for only three percent of the total amount of water on Earth. Of that three percent, only 0.003 percent is clean and safe, and available for human consumption.

Water can be polluted by oil, industrial wastes, sewage, bacteria, sediments, solid wastes, and even heat. When power plants use water from rivers for cooling purposes, the water may be returned to the river several degrees hotter than it was originally. Organisms in the river cannot adjust to such quick changes in water temperature, and they may die. Water can also be polluted by pesticides and fertilizers that are used on farms and homeowners' lawns. Rain washes these chemicals out of the soil and into nearby water sources. Even though water is a renewable resource, it is expensive to clean polluted water.

Land Pollution

Did you drink a soft drink yesterday? If you did, what did you do with the can or bottle when you were finished? If you threw it in the trash, you were contributing to land pollution. Magazines, newspapers, plastic bags, glass bottles, aluminum cans, grass clippings, and leftover foods that are thrown away end up as solid wastes. **Solid wastes** are the unwanted products that are burned, buried, and dumped each year all over the world. Every day, each person in the United States throws away 1.8 kg of solid wastes. Most of this solid waste ends up in sanitary landfills.

What happens to the garbage in sanitary landfills? Grass cuttings, animal wastes, newspapers, and dead leaves are broken down by decomposers in the soil. Wastes that can be broken down into their chemical components are called biodegradable. Waste products that cannot be broken down by natural processes, such as aluminum cans and old tires, are called nonbiodegradable. Wastes that are nonbiodegradable create pollution problems for years.

Toxic wastes are chemicals that are byproducts of industrial processes. Many are known to cause cancer, birth defects, and other health problems. These wastes are packed in steel drums. If the drums are not sealed properly, chemicals leak out and pollute both soil and water.

In Your JOURNAL

In your Journal, write an article for the local newspaper about the wise use of water resources in your area. Discuss ways to conserve water and prevent pollution.

Soil and Forest Resources

Much of the land in Nepal lies on steep mountain slopes, where fuel for cooking is scarce. Families go higher and higher up into the mountains searching for fuel. They cut trees and bring them home, leaving the slopes bare. When the rainy season comes, there are no tree roots to absorb water and hold soil in place. Water washes soil away. **Erosion** is the loss of soil from the effects of wind, water, or ice. Rain washes away the fertile topsoil, and trees are unable to grow on the barren mountain slopes.

Poor farming and forestry practices such as those described above often result in erosion of topsoil. It takes between 500 and 1000 years for 2.5 centimeters of topsoil to form. If rain falls after a farmer plows but before crops begin to grow, erosion may occur. Erosion also occurs when the timber in a forest is harvested by a method called clear-cutting. In this method, all the trees in a section of forest are cut down and dragged out. Not only is the soil left unprotected, but the habitats of all the organisms that live in or on the trees have been disturbed.

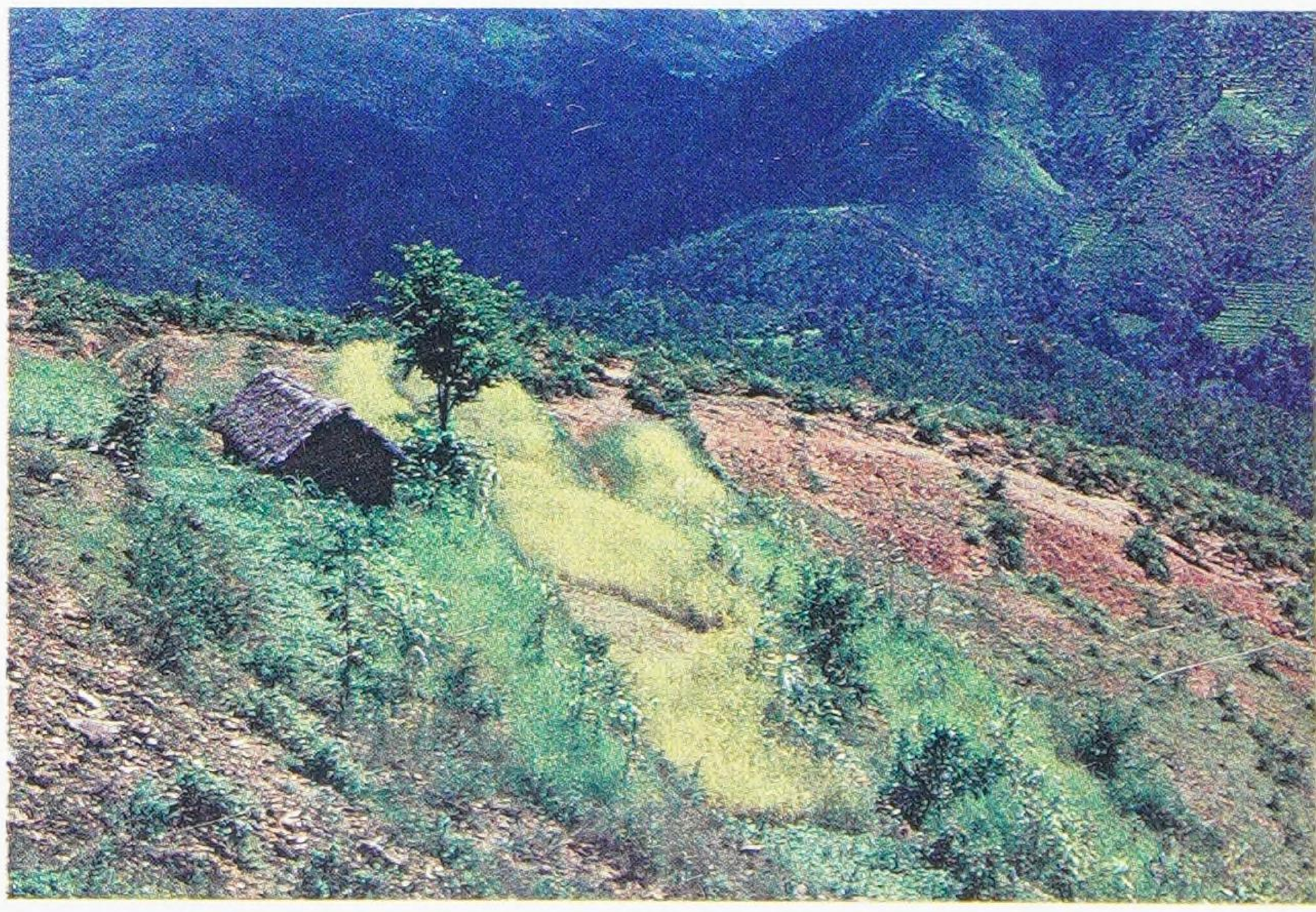


Figure 28-3. When trees are cut for firewood on steep mountain slopes, rain washes topsoil away.

DESIGNING AN EXPERIMENT

ACTIVITY 28-1

Investigating Biodegradable Substances

When you last emptied the garbage, did you notice how much trash there was? Think of all the trash other people in the United States produce in one year. The disposal of solid waste has become a serious problem for many communities. A common means of disposing of garbage is to add decomposed materials to landfills. Landfills are reaching their maximum capacity or have already been filled. Because of the amount of garbage produced, improved methods of disposal are needed.

In Chapter 3, you learned about organic and inorganic substances and nonbiodegradable substances in your environment. In this experiment, you will be the scientist and determine what kinds of substances are biodegradable.

Getting Started

In preparation for designing your experiment, answer the following questions:

1. What question are you investigating?
2. What variables are important in this experiment?
3. What causes substances to decompose naturally in the environment?
4. What happens to the materials in biodegradable substances that are released into the environment?

Safety Notes

Wash hands often when working with these materials.

Hypothesis

What is your **hypothesis?** What is the reasoning behind your hypothesis? Share this information with your group and decide on a group hypothesis.

Brainstorm

As a group, make a list of possible ways to test your hypothesis.

Experimental Plan

- **Design an experiment** to test one variable. Make sure you plan to collect quantitative data.
- In a numbered list, similar to a recipe, make a set of directions that anyone can follow to do the experiment.
- Make a list of materials and the quantities needed to do the experiment.
- Develop a data table and write in your data as you collect it.

Answer the Following Questions

1. Have you included a control? Explain.
2. What will you measure?

Make sure your teacher has approved your experimental plan before you go further.

Data and Observations

1. Carry out your experiment.
2. Make a table of your data.
3. Make a line graph showing the length of time it takes for different substances to decay.

Data Analysis and Interpretation

1. Was your hypothesis supported by your data? Explain.
2. Were there sources of error in your experiment? What were they?
3. If your hypothesis was not supported, what do you conclude?
4. Which substances were biodegradable?
5. Which substances decomposed first?
6. How can you use what you have learned in this investigation?
7. How can people reduce the amount of waste they produce?

Wildlife Resources

Have you heard of the California condor? Only about 40 of these huge birds still exist, and all of them are in captivity. Condors are in danger of becoming extinct because there are so few of them left. Many species of plants and animals today also are in danger of becoming extinct because they are hunted, or because their habitats have been destroyed. Species that are in danger of becoming extinct are called endangered species.

Populations of many wild species have been decreasing, often as a result of human activities. Developers have filled in estuaries and wetlands to build housing developments, farmers have plowed grasslands to plant crops, and lumber companies have cleared forests for timber. Some wildlife species are able to survive changes like these. Raccoons often do well in housing developments, as long as they can get into garbage cans! But many times these changes in wildlife habitat are so fast that species are unable to adapt. As a result, populations decline as individual organisms die or move on to better areas.

Plant species can be important sources of food and medicines, yet many plant species are endangered also. There may be thousands of plant species in tropical rain forests that have not been studied yet, and their uses are unknown. This is one reason that scientists would like rain forest destruction to stop.

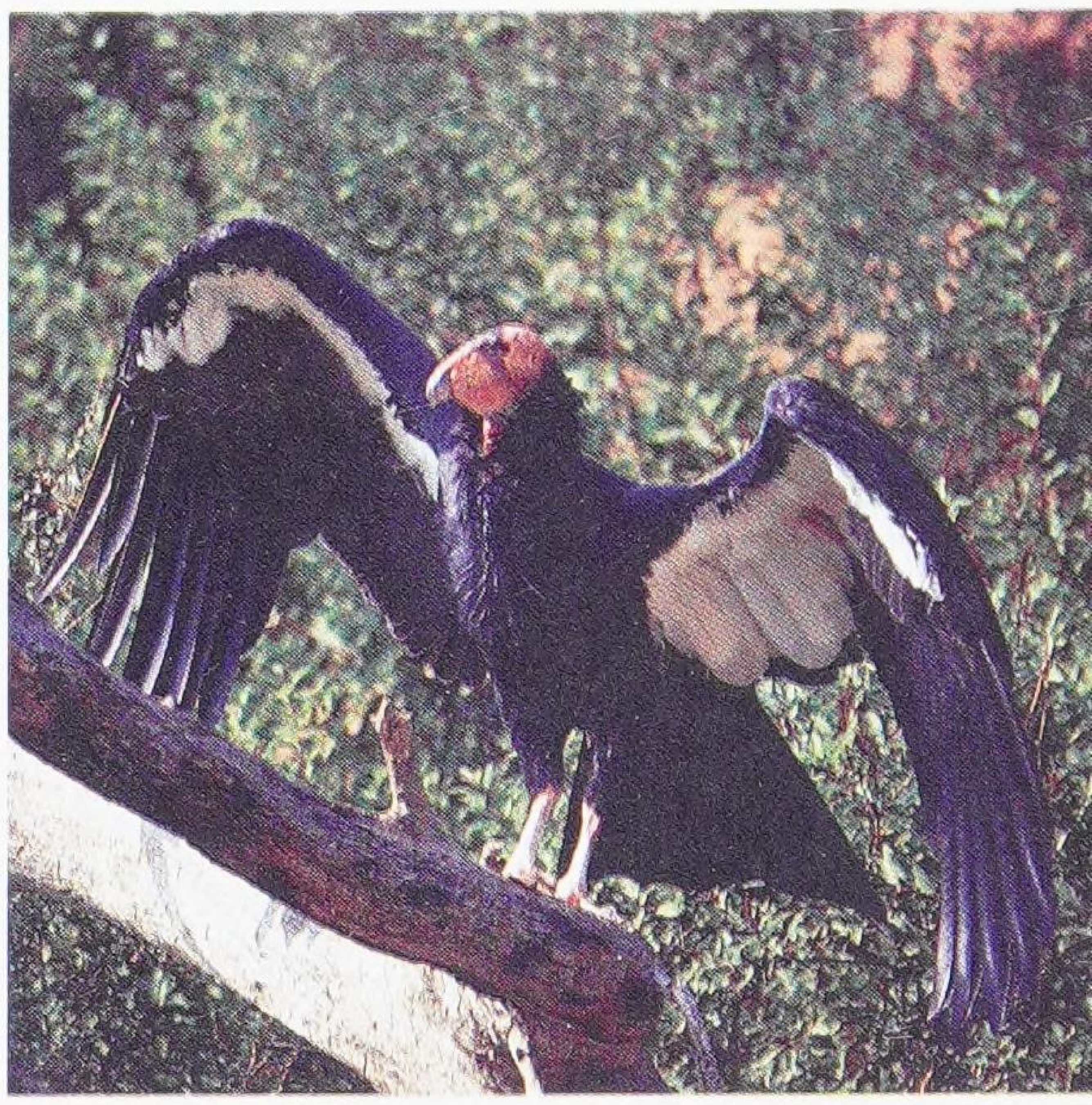


Figure 28-4. California condors are endangered as a result of habitat loss.

Why can't species adapt to changes in their habitat?

In Your JOURNAL

Choose an endangered plant or animal and research it. **In your Journal,** describe how this species became endangered.

SECTION REVIEW

1. What are natural resources?
2. Differentiate between renewable and nonrenewable resources.
3. Explain the greenhouse effect.
4. **Apply:** How have human activities increased the number of extinct plants and animals?
5. **Connect to Earth Science:** Find out how the cutting of trees affects global warming.

Skill Builder

Hypothesizing

Hypothesize why a population of raccoons is able to survive changes in its habitat. Explain. If you need help, refer to Hypothesizing in the **Skill Handbook** on page 686.

28-2 Conservation and Protection

New Science Words

conservation
reforestation
wildlife preserve

Objectives

- Define conservation and how it relates to natural resources.
- Describe how renewable resources can be conserved and protected.
- Identify ways to reuse nonrenewable resources.

What Is Conservation?

For thousands of years, farmers in steep mountain regions of Nepal, Myanmar, Indonesia, and the Philippines have terraced the sides of mountains to grow rice. They learned that terraces prevent soil erosion and hold water needed for rice production. These farmers practice soil and water conservation. **Conservation** is the wise and careful use of Earth's resources.

When humans use natural resources wisely, they can live in harmony with the community and environment around them. Because the human population continues to grow, people are becoming more aware of how important it is to conserve and protect our natural resources. There are many ways to balance the human need for natural resources with the availability of those resources. How can people clean up the air and water we rely on for life? What can be done about waste disposal? In this section, you'll see some ways people can make better use of natural resources.

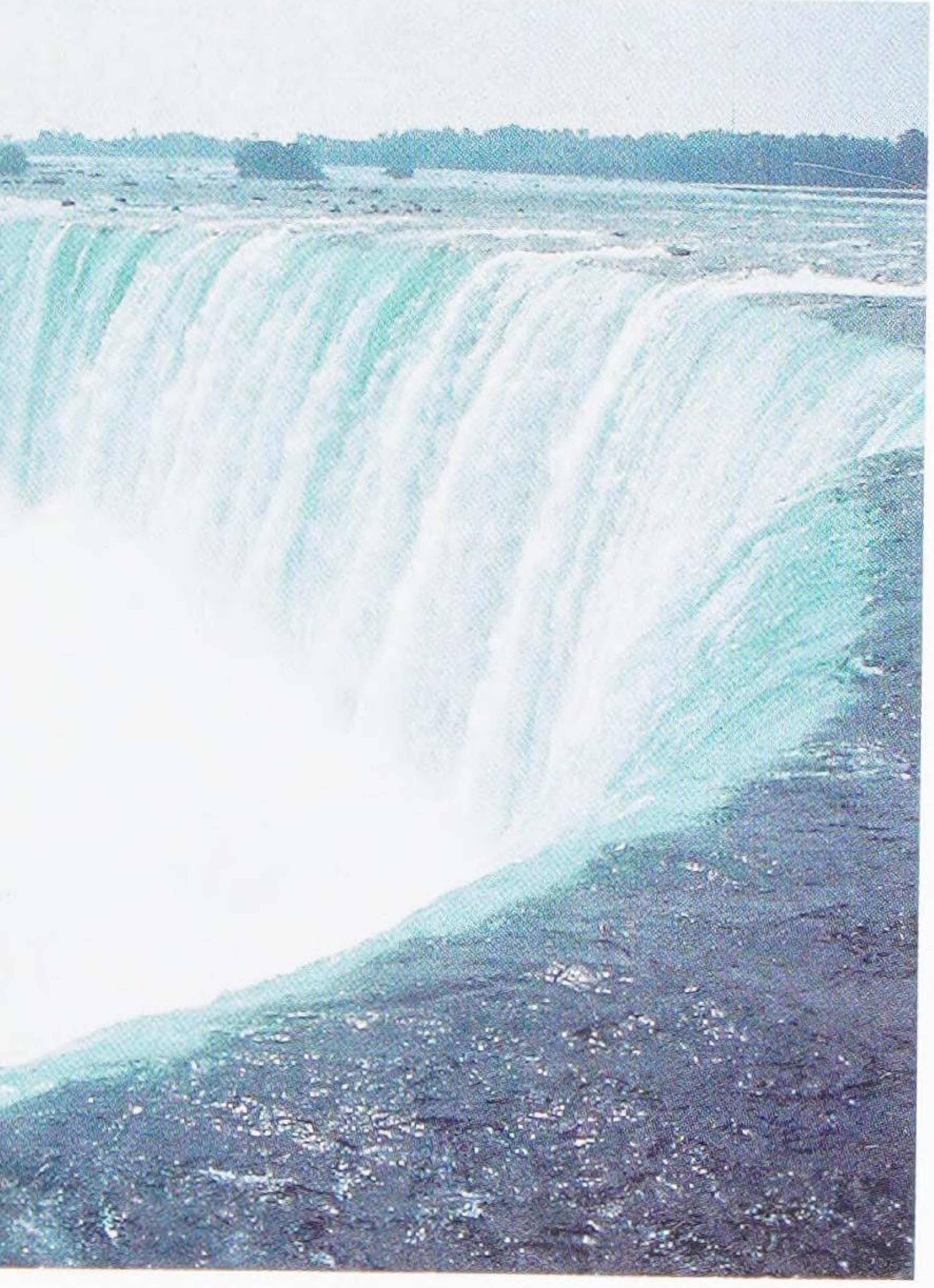


Figure 28-5. Kinetic energy in falling water is used to produce other forms of energy, such as electric power and mechanical energy.

Cleaning Up the Air

What kind of gasoline does your family's car use? If it is a late model car, it probably uses unleaded gas. Lead was a common component of most gasoline until 1970 when the Clean Air Act was passed in the United States. Since that year, all new cars have been designed to use only unleaded gas. The Clean Air Act of 1990 requires industries to reduce their sulfur dioxide emissions by 40 percent by the year 2000.

Reducing acid rain is a major focus of international groups today. At least 34 countries have agreed to work on solutions to the worldwide problem of air pollution. One way to reduce sulfur dioxide emissions is to change to another, renewable source of energy. In the desert, solar panels are now used to collect solar energy during the day. At night, this stored energy is used to produce electricity. Modern windmills like those shown in Figure 28-6 generate electricity that can be stored in batteries. Hydroelectric power has been used for many years all over the world. For example, the force of falling water turns turbines to generate electricity used by the city of Niagara Falls, New York. In the future, each country or region in a country may rely on local sources of energy rather than power plants operating far away. What renewable energy sources may be found where you live?

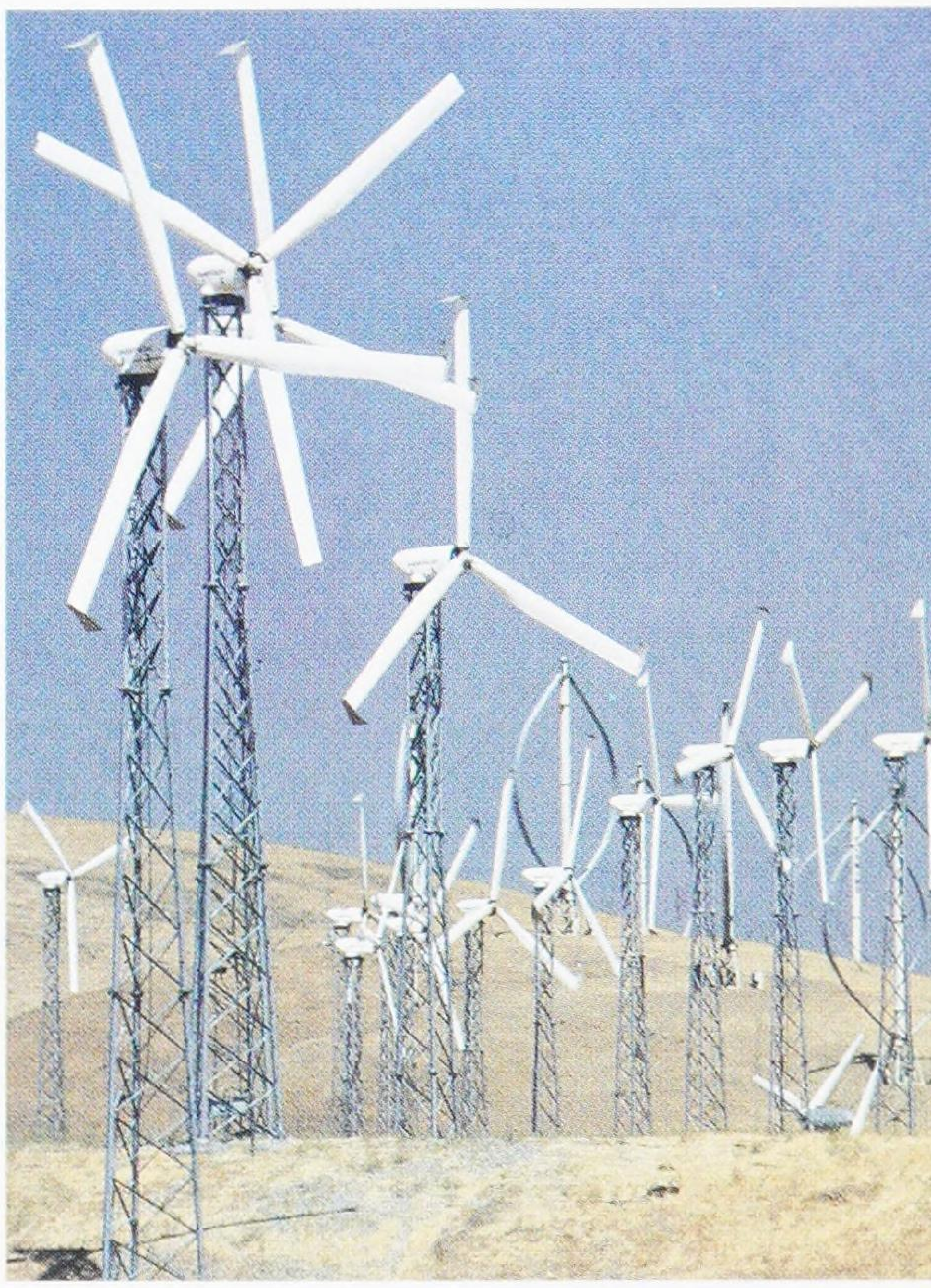


Figure 28-6. Modern windmills harness wind energy in places where the wind blows constantly and steadily.

Cleaning Up the Water

When you brush your teeth, do you leave the water running? If you do, you are wasting water! Even though water is Earth's most abundant resource, safe, clean drinking water is scarce. Many communities must spend enormous amounts of money cleaning up water or finding clean water sources. Nearly every large community has water treatment plants that kill bacteria and filter out sediments from the water supply. Some communities reuse water. For example, water used to wash clothes could be recycled and used for washing streets or cars. Some communities have programs that help people learn to conserve water at home.

Farmers conserve soil and water by changing the way they farm. Contour plowing allows farmers to plow across fields to slow down erosion. Terracing is a way to prevent erosion in hilly areas. Today, many farmers no longer plow their fields each spring. Instead, they plant new seeds right through the leftover stubble of the last crop. Farmers can also reduce water pollution by conserving soil and reducing the need for fertilizers and pesticides.

Connect to... Chemistry

You've read about pH on shampoo bottles. The acidity of a solution is determined by using the pH scale. Substances with a pH lower than seven are acids. The lower the pH number, the stronger the acid. Substances with a pH above seven are bases. The natural pH of rainwater is about 5.0 in the eastern United States and between 5.3 and 6.5 in the western states. Find out what the pH of acid rain is.

Waste Disposal

Have you ever helped clean up a park or roadside? Wastes are natural resources in different forms. Newspapers, glass bottles, aluminum cans, and even plastic milk cartons are made from natural resources. Paper products come from trees and can be recycled. Glass, aluminum, and plastic are made from nonrenewable resources. It only makes sense to recycle these resources.

Today, communities all over the world recycle to reduce wastes and reuse precious natural resources. Some cities collect grass clippings and dead leaves and take them to a community composting facility. Other cities have built trash-burning power plants that use trash to produce electricity. Industry sees the potential for recycling plastics. In Chicago, one company recycles 2 million plastic milk jugs a year into "plastic lumber."

Protecting Soil and Forest Resources

Lumber companies in the United States practice selective cutting in which the largest, shade-producing trees are removed from a forest. This provides smaller trees with more sunshine so they grow at an even faster rate. **Reforestation** is the process of replanting a cut-over area with seedling trees. Reforestation helps to reduce soil erosion because the new trees absorb rainwater, and their roots hold soil in place.

Many countries have made efforts to protect forest resources by developing national parks and forests. In Nepal and India, forestry officials are educating farmers about reforestation and helping people create their own forests to harvest for firewood. Fast-growing tree seedlings are planted in community forests so that local people learn how to care for and manage forest resources.

Did You Know?

Today, the United States has 300 million hectares of forested lands, 20 percent more trees than it had 20 years ago.

Figure 28-7. Some endangered species may recover and increase in population size once laws are made to protect them and their habitats.

Protecting Wildlife

Even though extinction is a natural process, the rate of extinction of wildlife today is very high. Countries such as Kenya and Tanzania protect endangered species by creating national parks and wildlife preserves. A **wildlife preserve** is an area of land set up to protect wildlife species. Hunting and fishing are prohibited in wildlife preserves to ensure that endangered species come to no harm. Out of more than 1000 species of endangered wildlife worldwide, more than half are in the United States.

Not every endangered species becomes extinct. In fact, since 1900 several endangered species in the United States have recovered as a result of laws that protect these species and their habitats. The wild turkey, pronghorn antelope,

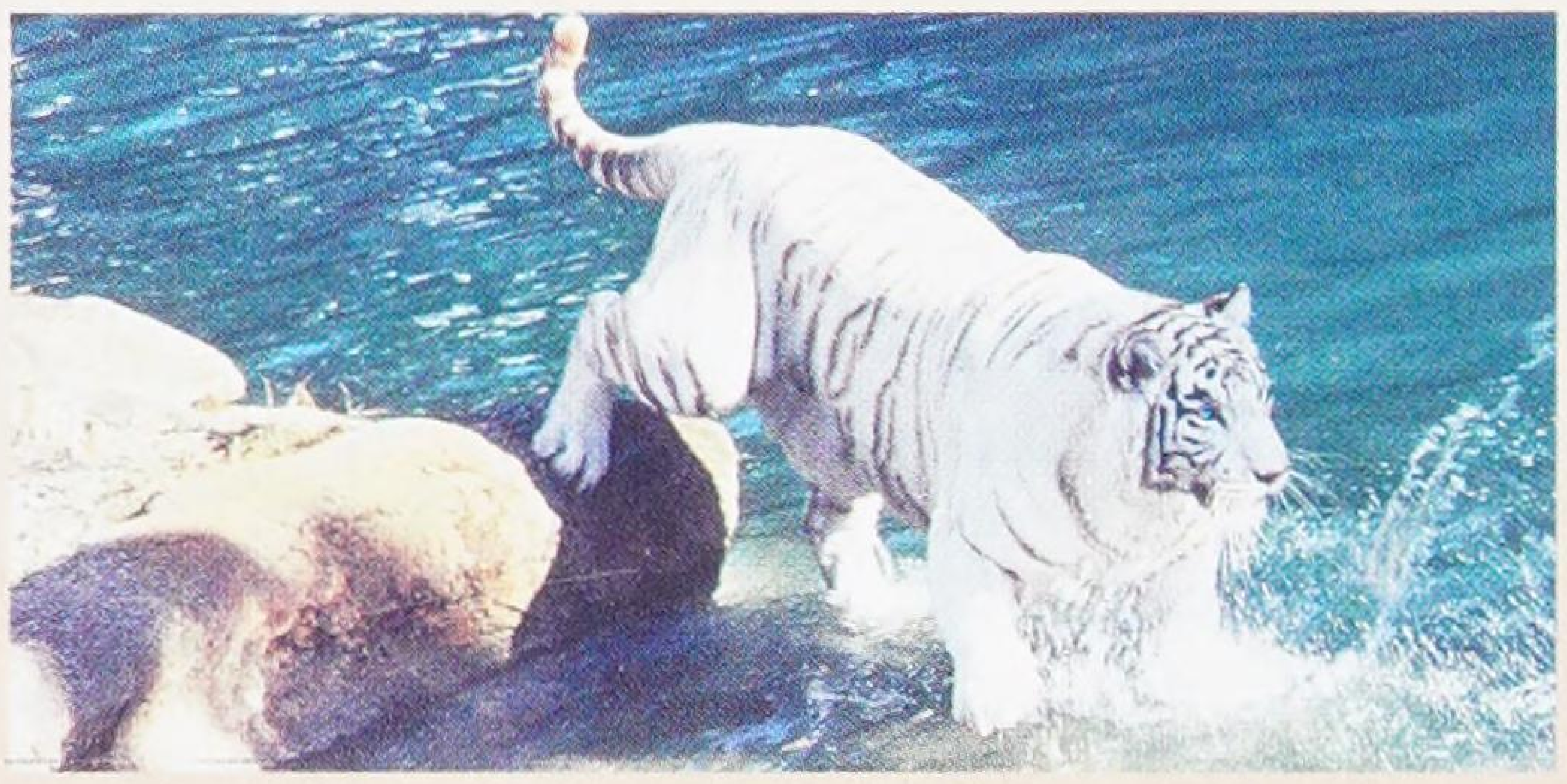
TECHNOLOGY

Test Tube Tigers

Wild Bengal tigers have been pushed into isolated areas by human encroachment into their habitat. This separates potential mates and increases the chance of inbreeding. Captive populations also have breeding problems. Nicole, a captive Siberian tigress, became the first surrogate tiger mother when she gave birth to cubs conceived through in vitro fertilization.

Nicole and two Bengal tigresses were given an injection to induce ovulation. Ripe eggs were extracted from the Bengal tigresses and mixed in a petri dish with sperm from a white tiger. Fifteen embryos were implanted in Nicole. She gave birth to three Bengal tiger cubs. The male cub and one female did not live long due to medical problems, but the second female is fine.

Think Critically: How could in vitro fertilization be used to help wild populations?



bison, bald eagle, and American alligator are five species that have gone from near extinction to large numbers of individuals today. Wildlife preserves, new conservation laws, and public education programs help to conserve wildlife and protect wildlife habitats.

SECTION REVIEW

1. Define two conservation methods used by farmers.
2. List three sources of energy that are renewable.
3. Why can recycling aluminum conserve resources?
4. How does reforestation conserve soil and forest resources?
5. **Apply:** Describe three things that you can do to conserve and protect natural resources.
6. **Connect to Chemistry:** Find out how acid rain is formed.

Concept Mapping

Skill Builder

Draw a concept map that shows events that occur when a forest is clear-cut. Include the terms: *clear-cut, soil erodes, animal species leave, rainfall, no topsoil left, land unable to support plant life.* If you need help, refer to Concept Mapping in the **Skill Handbook** on pages 688 and 689.

28-3 Future Responsibility

New Science Words

environmental management

Objectives

- Explain the importance of environmental management.
- Identify ways in which individuals can contribute to environmental management.
- Describe ways in which individuals can conserve and protect natural resources.

Environmental Management

If you are an architect thinking about building on a hilly site, what do you need to know? You need to know the soil type and whether there is rock underneath to support the building's weight. If there will be landscaping around the finished building, you may want to preserve the large trees that are growing there. If there is a stream at the bottom of the hill, you may have to control erosion during construction. Looking carefully at natural resources and thinking about how your actions will affect the site is one example of environmental management. **Environmental management** is the use of methods that conserve resources and protect ecosystems.

With so many people on Earth, natural resources and ecosystems are under a lot of pressure. Whenever a development is planned, its effects on the environment must be considered and weighed against the benefits. When the Alaska oil pipeline was built, many people were concerned about damage to wildlife populations and the permafrost. These environmental hazards had to be weighed against the benefits of the pipeline. In many cases, changes made at the planning stages can reduce or eliminate damage to the environment.

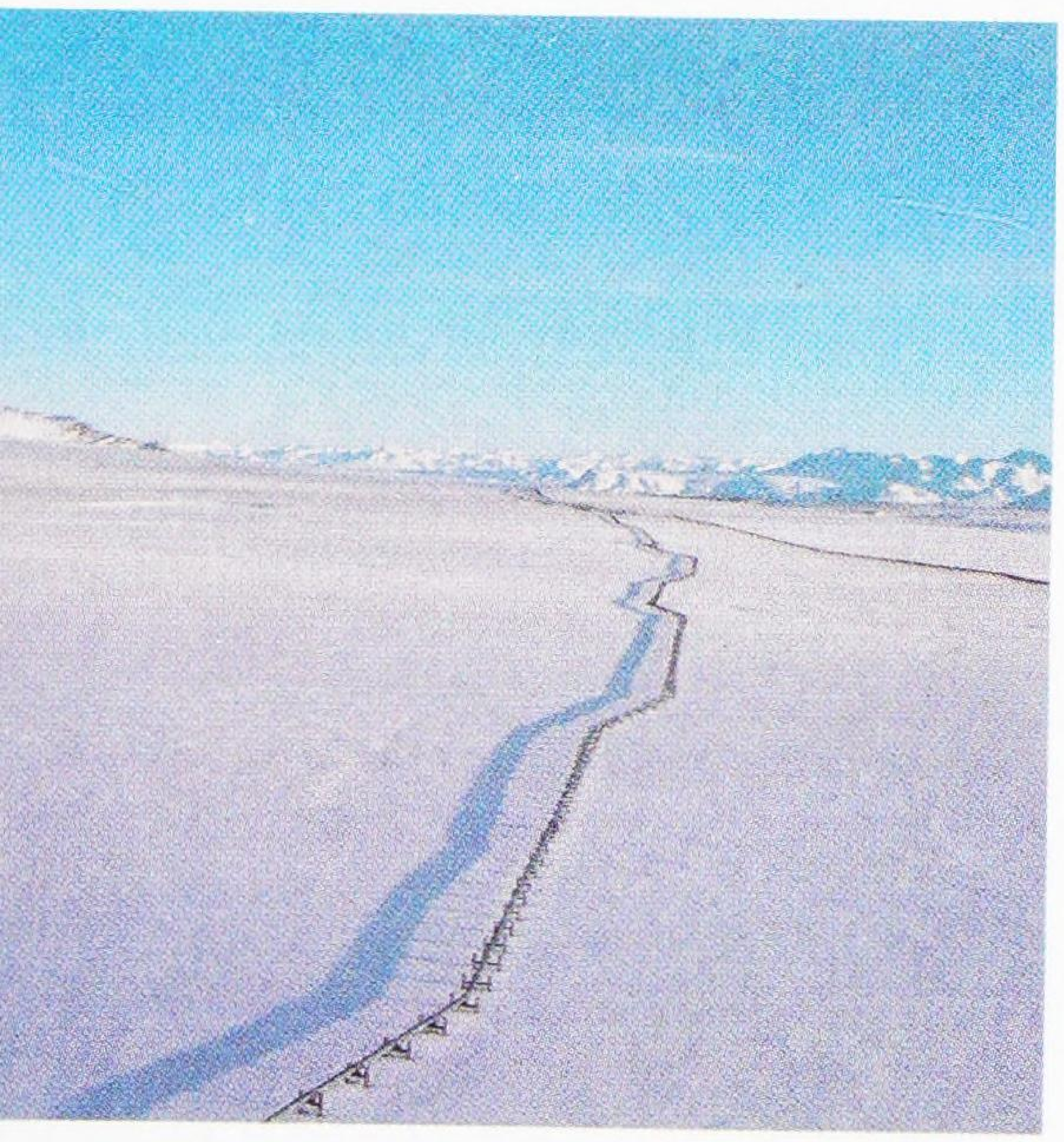


Figure 28-8. In planning for development, the needs of wildlife must be considered along with the potential benefits of the project.

Individual Responsibility

Have you ever bought an apple at a grocery store and bitten into it, only to find a worm? Chances are this has never happened to you because commercial apple growers spray pesticides on their trees to prevent damage from pests. Would you purchase apples with wormholes if they were grown without chemicals? What are you willing to do to help protect and conserve natural resources?

In your community the police, sanitation workers, school teachers, firefighters, and homeowners all have responsibilities. You have the responsibilities of going to school, doing homework, and helping at home. Everyone must obey laws. But in addition to these, every person in your community also has responsibilities to the environment in which he or she lives.

What can you do to help? Help your family separate household garbage and recycle glass, plastic, aluminum, and paper. Use leftover foods to make a compost pile, and use the compost to improve your garden's soil. Take your shopping bag to the grocery store, and don't buy prepackaged foods. Always turn off the lights when you leave a room. These are things you can do to save energy, use resources wisely, and improve the environment.

In your community, you can volunteer your time to a conservation or environmental organization. If your school or community doesn't have a recycling program, start one! Begin a tree planting program, or ask your class to adopt a stretch of highway. Make sure that used oil, paint, and batteries are disposed of properly. Remember—there is only one Earth, and all life depends on Earth's limited resources. If each person conserves and protects these resources, life on Earth will continue to amaze and delight for years to come.

MINI-Lab

How many families in your school recycle?

With the help of your teacher and approval of your principal, develop a survey that can be sent home asking families if, what, and where they recycle. Set a deadline for the return of the papers. *Organize* a way to tally the *data* and be sure to report to the families on the results. Try to use recycled paper for this activity!

SECTION REVIEW

1. Why is environmental management important?
2. Name four things you can do to help conserve and protect natural resources.
3. **Apply:** If building a house on a site will result in erosion that will affect a stream, what could the builder do to eliminate the erosion? Explain.
4. **Connect to Chemistry:** How might a pesticide such as DDT be present in species other than the crop-eating insects it was intended to kill?

Skill Builder

Recognizing Cause and Effect

List as many causes and effects of pollution in your community as you can. Suggest ways each source could be reduced or eliminated. If you need help, refer to Recognizing Cause and Effect in the **Skill Handbook** on page 683.

SCIENCE & SOCIETY

28-4 Earth in 2030

New Science Words

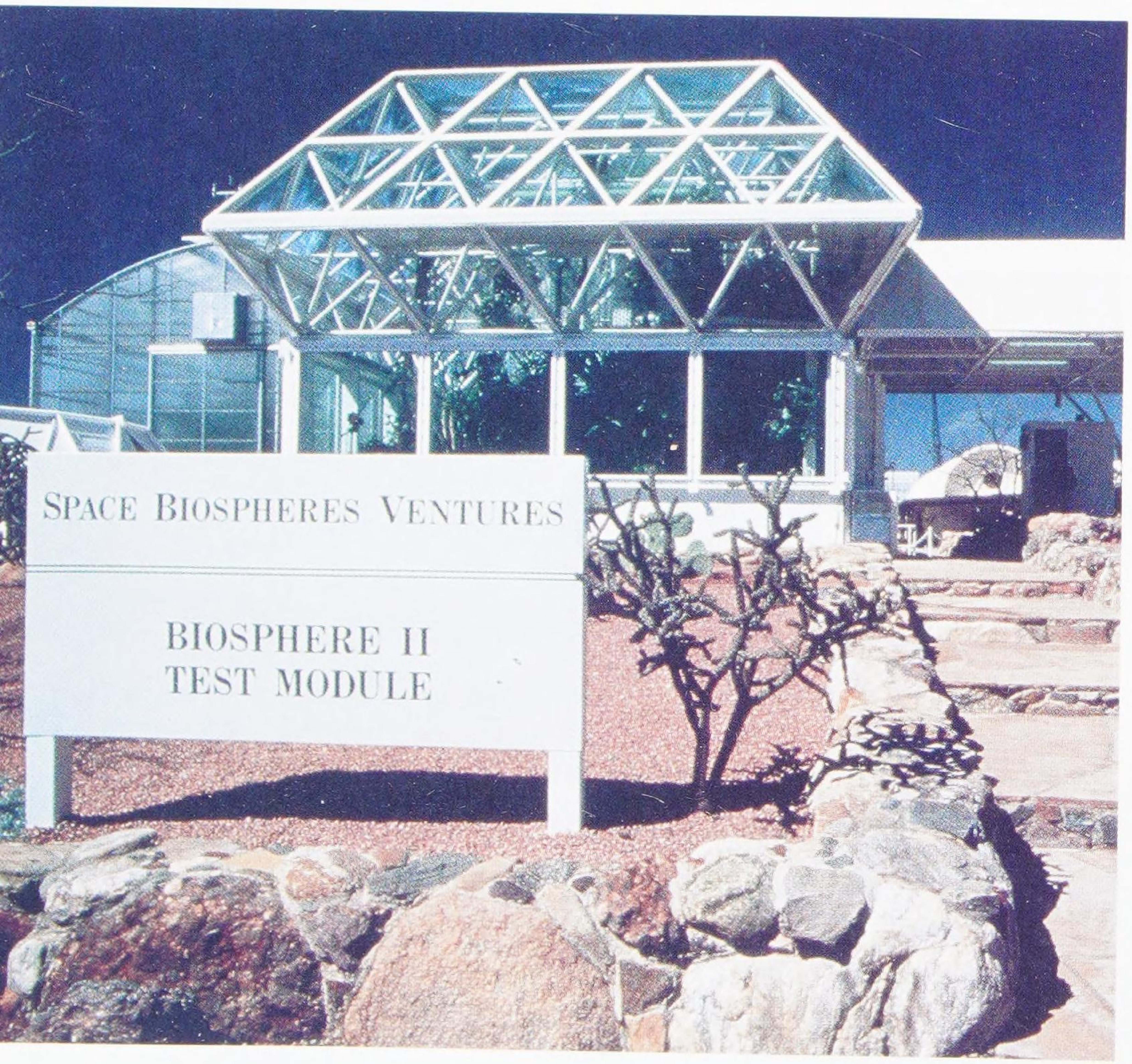
environmental activists

Objectives

- Identify three issues that concern environmental activists.
- Describe ways to improve environmental conditions on Earth.

The Future: Grand or Grim?

Pretend you're in a time machine heading for the year 2030. You are hoping for the best, but you know that when you left the 1990s things were looking grim. Earth's population had nearly doubled between 1960 and 1990. More than 400 hectares of forest were being destroyed each day. Pollutants in the air were causing global warming and acid rain. In the United States, people were throwing away 160 million tons of solid waste every year. They were not thinking about the environment of future generations.



As you leave the time machine in the year 2030, you are very afraid of what you might find. Will the world still exist? What if you can't return? To your surprise, Earth is beautiful. It soon becomes apparent why. Huge numbers of people became **environmental activists,** people who worked to conserve Earth's resources and protect the environment.

The plastic containers that you sent to the recycling center are still here, although you don't recognize them. They've been molded into building material that is used to make park benches. No coal, oil, or natural gas is sold. Nuclear energy is not avail-

able either. Solar energy and wind and water power are the main sources of electricity now. Homes are super-insulated to prevent cooling or heating. People don't drive to work, but walk or bike instead. Many people work in their homes and communicate with the office by computer or telephone. Even shopping is done from the home through computers. Air quality is good because deforestation was stopped in the year 2000. Landfills are no longer used, and everything is recycled over and over again. Nearly all material used in industry is made from recycled products, including the clock that tells you it is time to head back to the 1990s!

Connect to...

Physics

Plutonium is a radioactive element used as a fuel in nuclear reactors. Find out some of the characteristics of this fuel as they affect the human body.

SECTION REVIEW

1. Name three environmental crises that need our immediate attention.
2. What are three things that you can begin doing today that will affect Earth tomorrow?
3. **Connect to Physics:** Give examples of renewable energy sources.

You Decide!

SCIENCE & SOCIETY

In the United States, most energy for heat and electricity is produced by burning fossil fuels. Nuclear power generation is a much cleaner process, yet it results in radioactive wastes such as plutonium. Most used plutonium is stored in vats of water at power plants because there is no material that can be used to make containers to hold plutonium for the 240 000 years it is radioactive. Should the United States switch from fossil fuels to nuclear power for its energy needs?

ACTIVITY 28-2

Identifying Air Pollution Sites

Problem: *Where can you find air polluted with particulates?*

Material

- 8 strips of cardboard 5 cm × 20 cm
- 4 strips of waxed paper 5 cm × 20 cm
- scissors
- hole punch
- string
- petroleum jelly
- stapler and staples

Procedure

1. Draw circles 3 cm in diameter in each of 4 strips of cardboard. Cut out the circles. **CAUTION:** *Use extreme care with scissors.* Label each 1, 2, 3, or 4.
2. Cover one side of a waxed paper strip with petroleum jelly.
3. Place the waxed paper strip behind the circles on the cardboard strip with the petroleum jelly facing out. Tape in place.
4. Cover the back of the waxed paper strip with a second cardboard strip. Staple the cardboard strips together.
5. Punch a hole in one end of the double cardboard strip. Place a piece of string through the hole and make a loop in it.
6. Hang each of the strips in a different location. Choose one location that is inside a building. Handle the strips carefully so that you do not touch the petroleum jelly in the circles. Tie each strip to an object with the string so that it will not blow away.
7. Record the locations.
8. **Hypothesize** which location you expect to have the most particulates.
9. Wait two days and collect the strips. Use care not to smudge the petroleum-coated sides.
10. Examine the circles on each strip with a hand lens. Record your observations.

Data and Observations

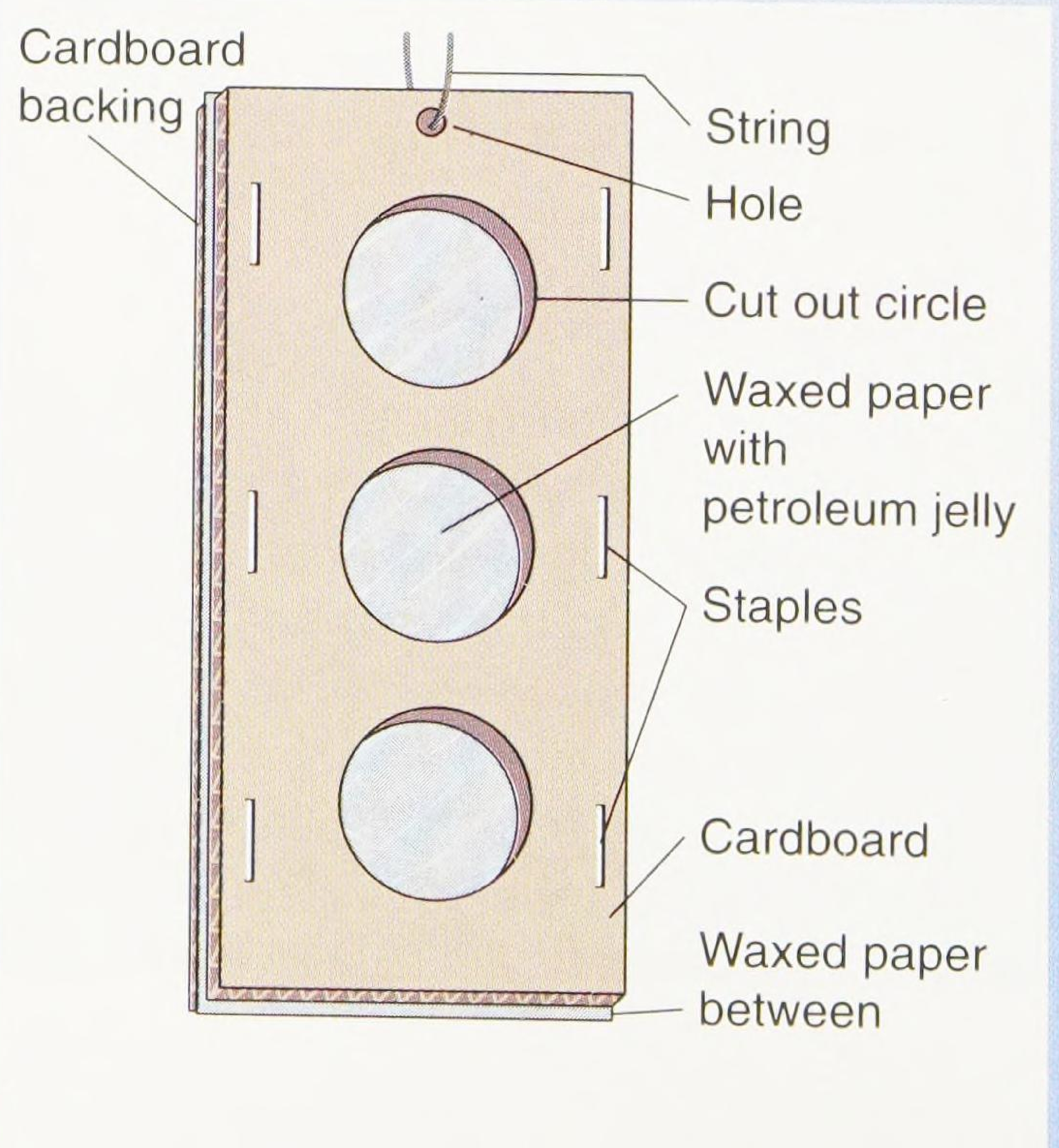
Strip	Location	Observations
1		
2		
3		
4		

Analyze

1. What particulates did you *observe* on the strips hung outside?
2. What particulates did you observe on the strip hung indoors?
3. Which site had the most air particulates?
4. Which site had the least air particulates?
5. How did your results *compare* with your **hypothesis?**

Conclude and Apply

6. Would you expect to find more or fewer particulates on a windy day? Why?
7. What types of air pollution cannot be detected on the strips?



CHAPTER REVIEW

SUMMARY

28-1: Natural Resources

1. All living things need natural resources such as air and water to stay alive.
2. Renewable resources can be replaced by nature. Nonrenewable resources are only available in limited amounts.
3. Human use of resources causes pollution of air, water, and land.

28-2: Conservation and Protection

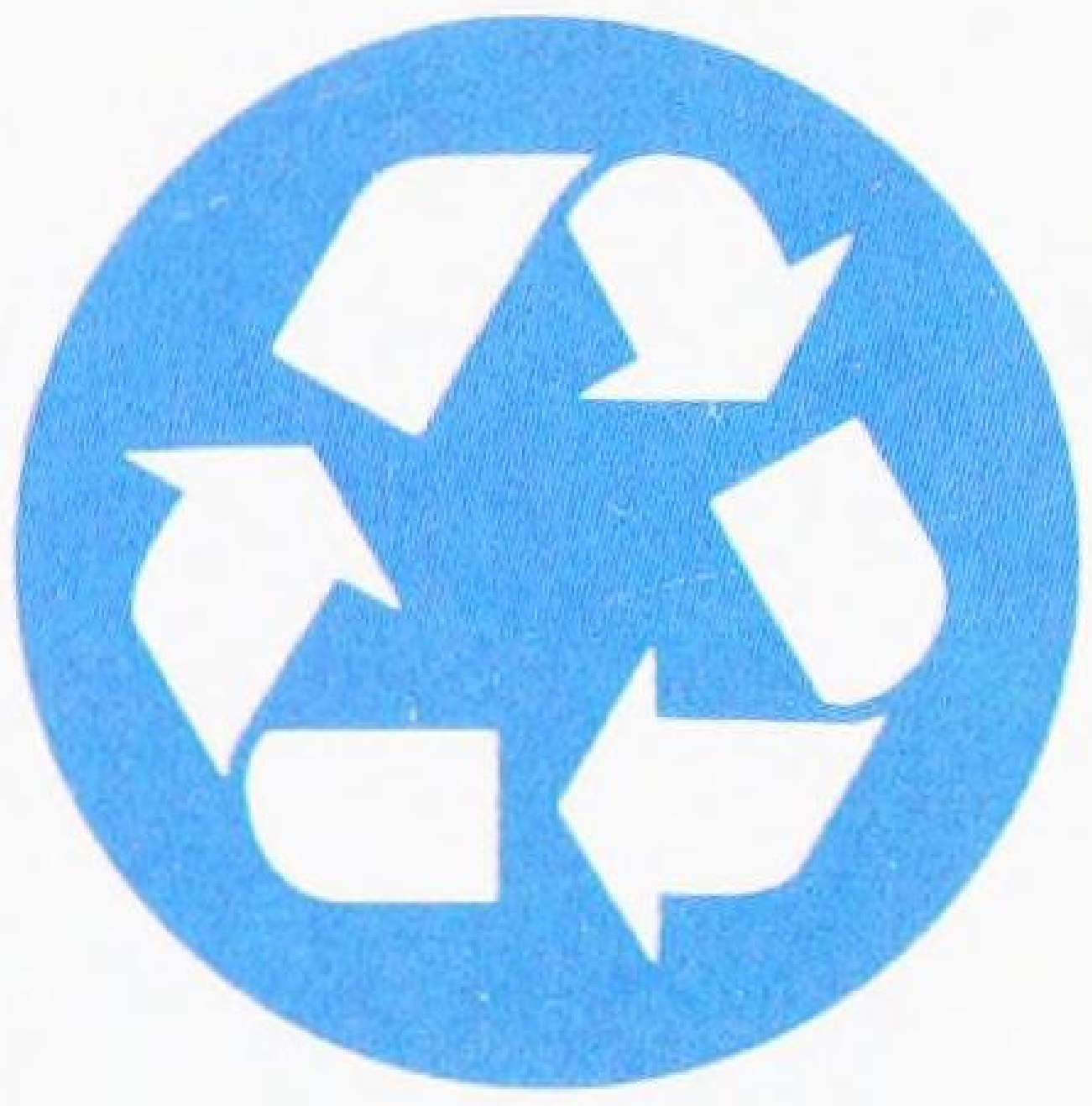
1. Conservation is the wise and careful use of natural resources.
2. Renewable resources are conserved through conservation and protection.
3. Nonrenewable resources are limited but can be recycled to be used again.

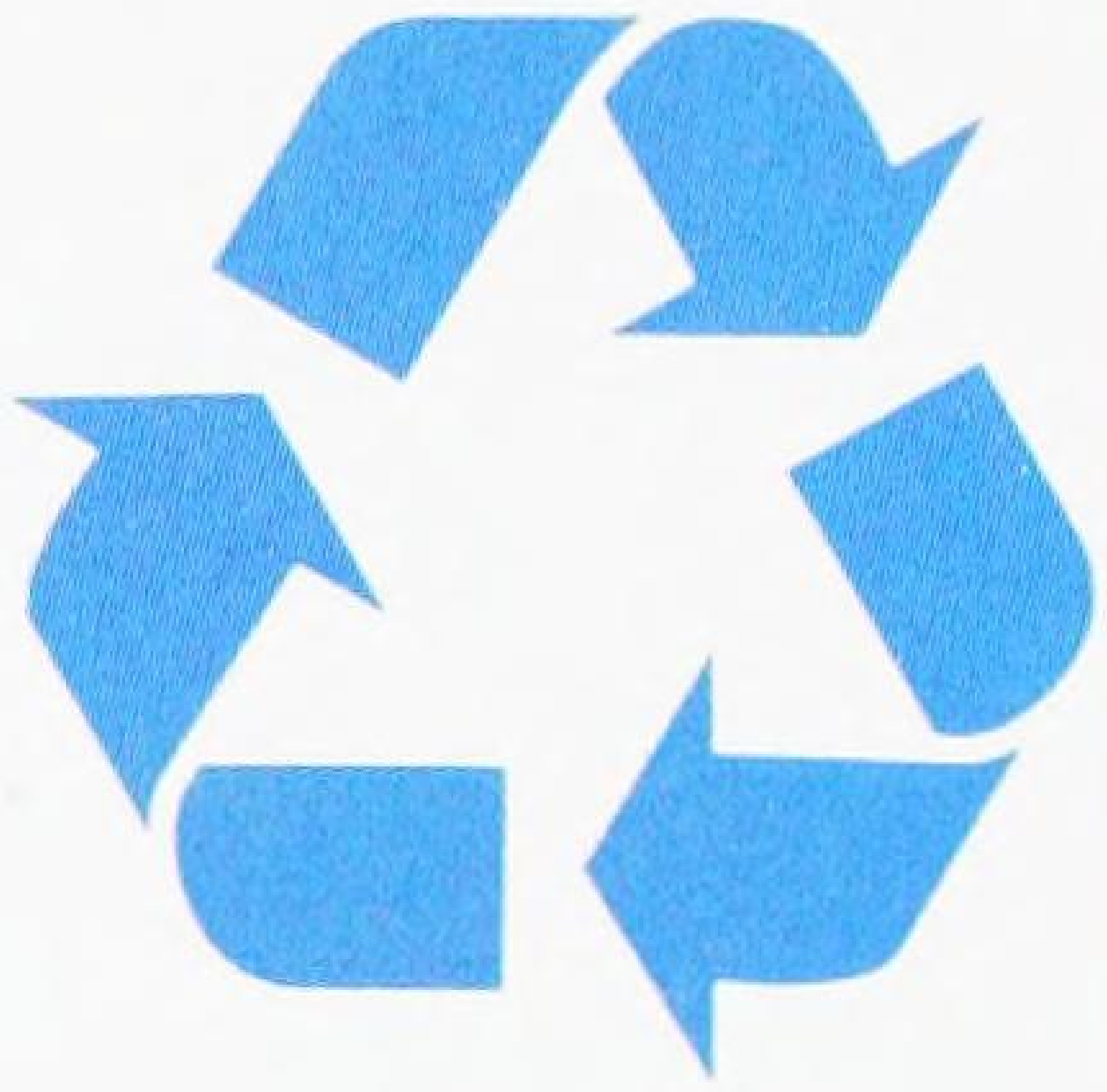
28-3: Future Responsibility

1. Environmental management uses methods to conserve resources and protect ecosystems.
2. Individuals can contribute to environmental management by giving consideration to the environment when development is planned.
3. Individuals can conserve and protect natural resources by recycling, using resources wisely, and becoming active members of environmental organizations.

28-4: Science and Society: Earth in 2030

1. Environmental activists work to conserve Earth's resources and protect the environment.
2. Finding renewable sources of energy and recycling nonrenewable resources lead to a better environment.


Recycled


Recyclable

KEY SCIENCE WORDS

a. **conservation**
b. **environmental activists**
c. **environmental management**
d. **erosion**
e. **greenhouse effect**
f. **natural resources**
g. **nonrenewable resources**
h. **reforestation**
i. **renewable resources**
j. **solid wastes**
k. **wildlife preserve**

UNDERSTANDING VOCABULARY

Match each phrase with the correct term from the list of Key Science Words.

1. loss of soil
2. land area for protected wildlife
3. resources that can be replaced by nature
4. raw materials in environment needed by organisms
5. unwanted waste products
6. resources that are limited
7. replanting after trees have been cut
8. retaining heat by Earth's gas layer
9. wise and careful use of Earth's resources
10. using methods to conserve resources

CHAPTER REVIEW

CHECKING CONCEPTS

Choose the word or phrase that completes the sentence.

1. Fossil fuels are _____.
   - a. renewable resources
   - b. responsible for most land pollution
   - c. responsible for most water pollution
   - d. formed from dead organisms
2. Nonrenewable resources include _______.
   - a. gold
   - b. solar energy
   - c. wind energy
   - d. trees
3. Air pollution is caused by all of the following except _______.
   - a. carbon monoxide
   - b. nitrogen oxide
   - c. sulfur dioxide
   - d. oxygen
4. Trapping of _______ causes the greenhouse effect.
   - a. carbon dioxide
   - b. carbon monoxide
   - c. sulfur dioxide
   - d. nitrogen oxide
5. Only _______ percent of water on Earth is clean and safe, and available for human consumption.
   - a. 3
   - b. 0.03
   - c. 0.3
   - d. 0.003
6. _______ is (are) nonbiodegradable waste.
   - a. Grass
   - b. Aluminum cans
   - c. Leaves
   - d. Vegetable peelings
7. _______ are in danger of becoming extinct.
   - a. Natural resources
   - b. Solid wastes
   - c. Wildlife preserves
   - d. Endangered species
8. Problems with sanitary landfills include all of the following except ______.
   - a. leaking drums
   - b. containing toxic wastes
   - c. little room left
   - d. containing biodegradable wastes
9. _______ can cause erosion of soil.
   - a. Fertilizers
   - b. Selective cutting
   - c. Reforestation
   - d. Clear-cutting
10. An example of an extinct animal is _______.
    - a. dodo bird
    - b. wild turkey
    - c. American alligator
    - d. bald eagle

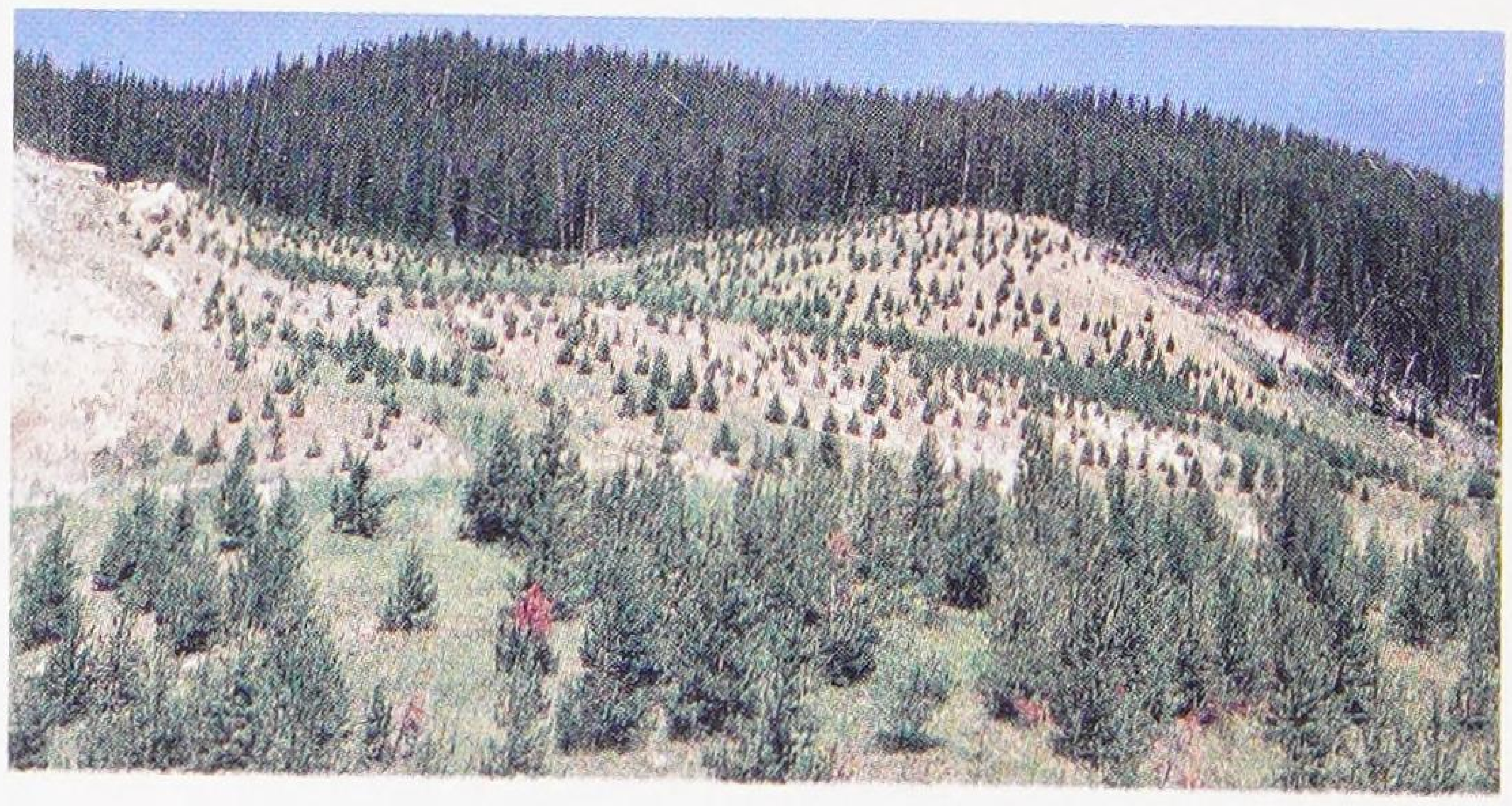
USING LAB SKILLS

11. In Activity 28-1, you studied biodegradable substances. Design an experiment to determine whether the following items are biodegradable: carrot scrapings, coffee grounds, tea leaves, paper bag, plastic foam cup, and plastic wrap from a package.
12. In Activity 28-2 on page 662, you identified air pollution sites. Wash and rinse a glass container in distilled water available at drug stores. Collect rainwater in the container and then allow the water to evaporate. What do you see? How did it get there?

THINK AND WRITE CRITICALLY

Answer the following questions in your Journal using complete sentences.

13. Distinguish between renewable and nonrenewable resources.



14. What is the importance of decomposers in a sanitary landfill?
15. How can environmental activists affect how resources are used?
16. What happens to land that has lost topsoil?

APPLY

17. Why is it beneficial to grow another crop on soil after the major crop has been harvested?
18. Explain the possible problems pollutants cause to water- and land-dwelling organisms.
19. Explain how car pooling saves fossil fuel.
20. What are the advantages gained by selective cutting rather than clear-cutting a forest?
21. Why is it important to do research now on solar energy, wind power, and water power?

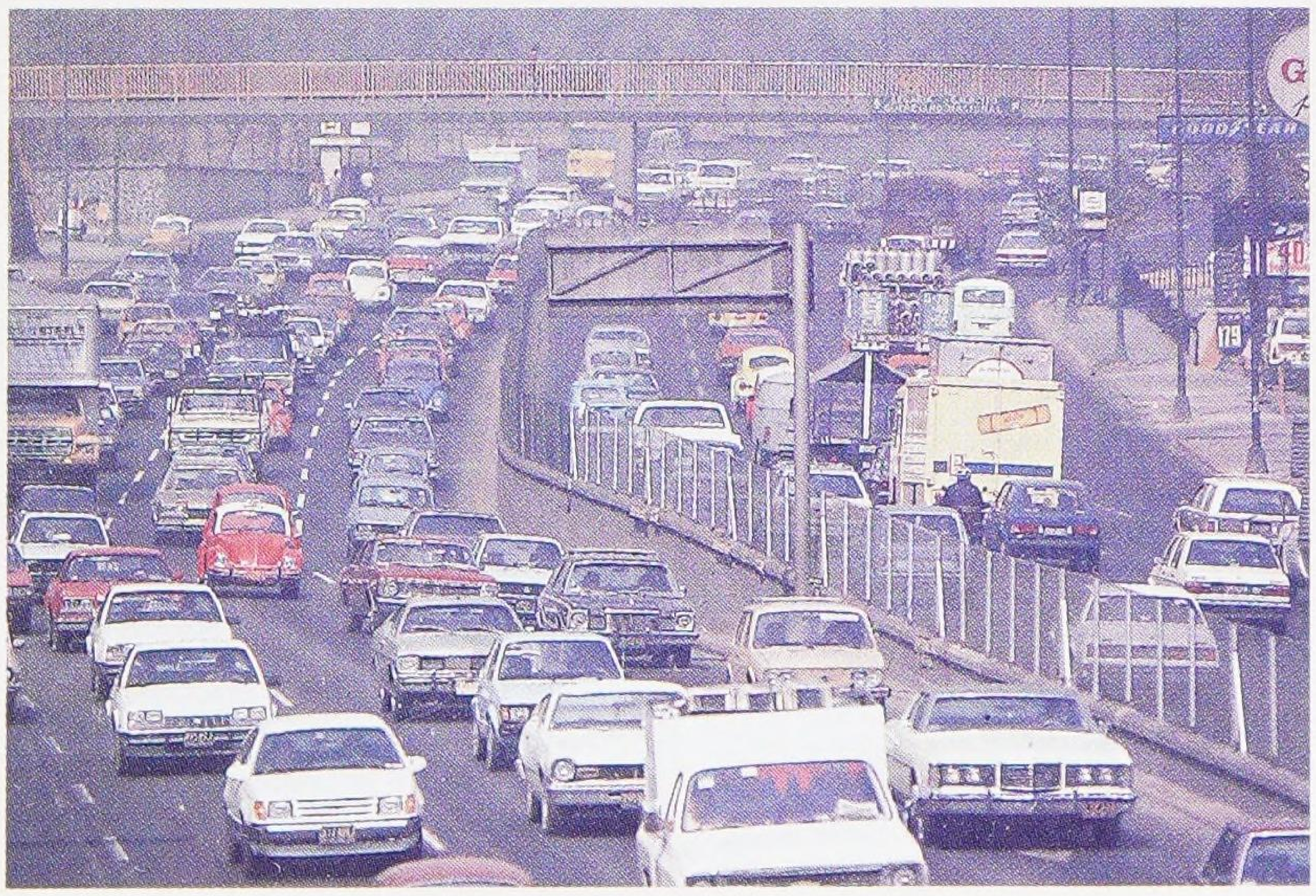
MORE SKILL BUILDERS

If you need help, refer to the Skill Handbook.

1. **Classifying:** Classify each of the following as renewable or nonrenewable: copper, gold, trees, iron, wildlife, fossil fuels, cotton.
2. **Sequencing:** Sequence the making and use of an aluminum can. Then recycle it!
3. **Using Variables, Constants, and Controls:** In an experiment, show differences in air pollutants produced by old and new cars.
4. **Concept Mapping:** Complete an events chain concept map using these occurrences:
   - organisms died millions of years ago forming. . .
   - fossil fuels such as petroleum, which is used to make plastic bags, cups, and . . .
   - gasoline which is burned by cars releasing the gases carbon monoxide and . . .
   - nitrogen oxide, which pollutes the air and returns to Earth in . . .
   - acid rain, which pollutes rivers, lakes, and forests, causing death of many organisms.

PROJECTS

1. Write a report on the recovery of animals that were endangered. How were they saved?
2. Find out what recycled items are available in your community and how you would be able to tell they are made of recycled materials.

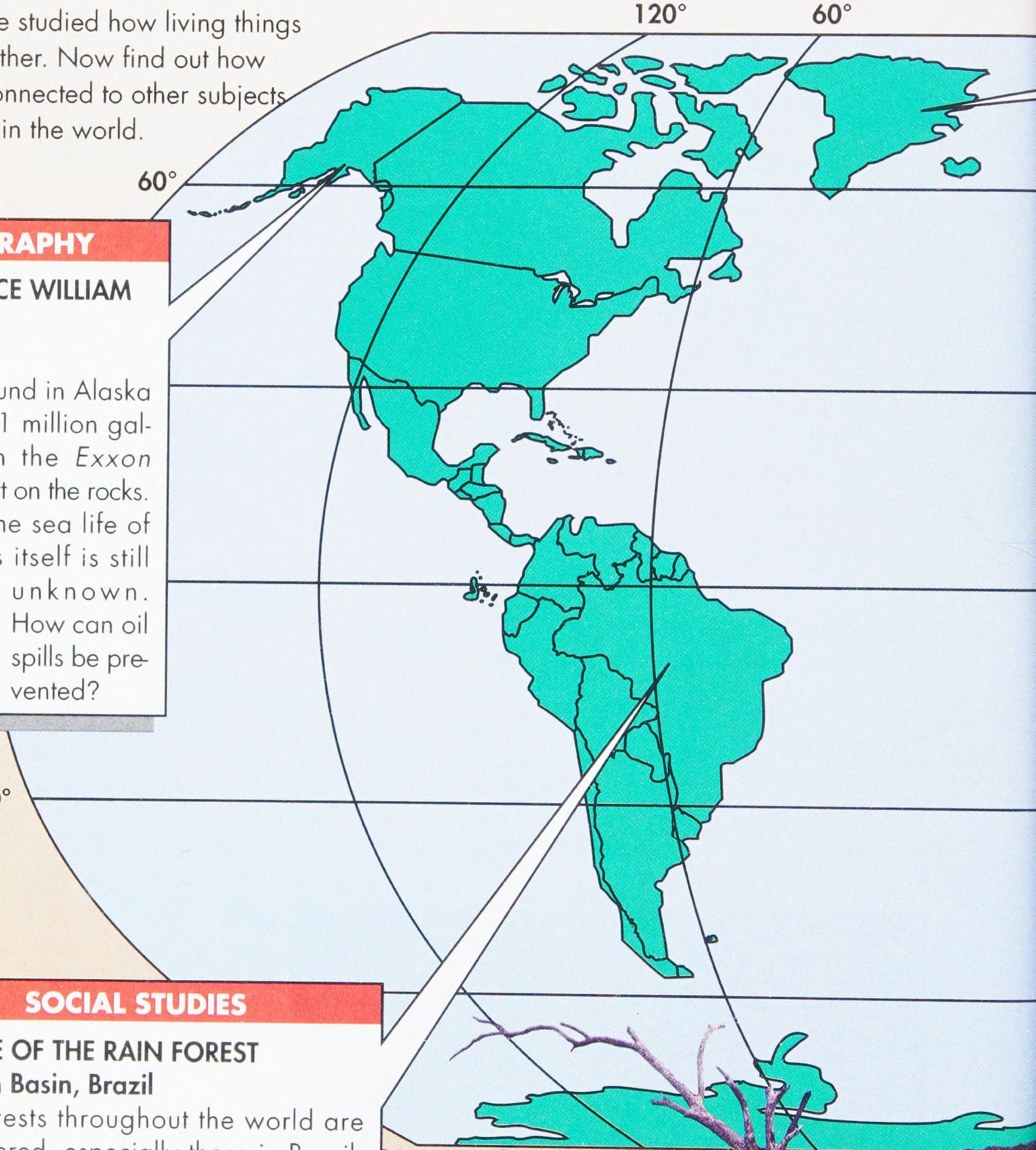


UNIT 8

GLOBAL CONNECTIONS

The Environment

In this unit, you have studied how living things interact with each other. Now find out how that interaction is connected to other subjects and specific places in the world.



OCEANOGRAPHY

OIL SPILL AT PRINCE WILLIAM SOUND

Valdez, Alaska

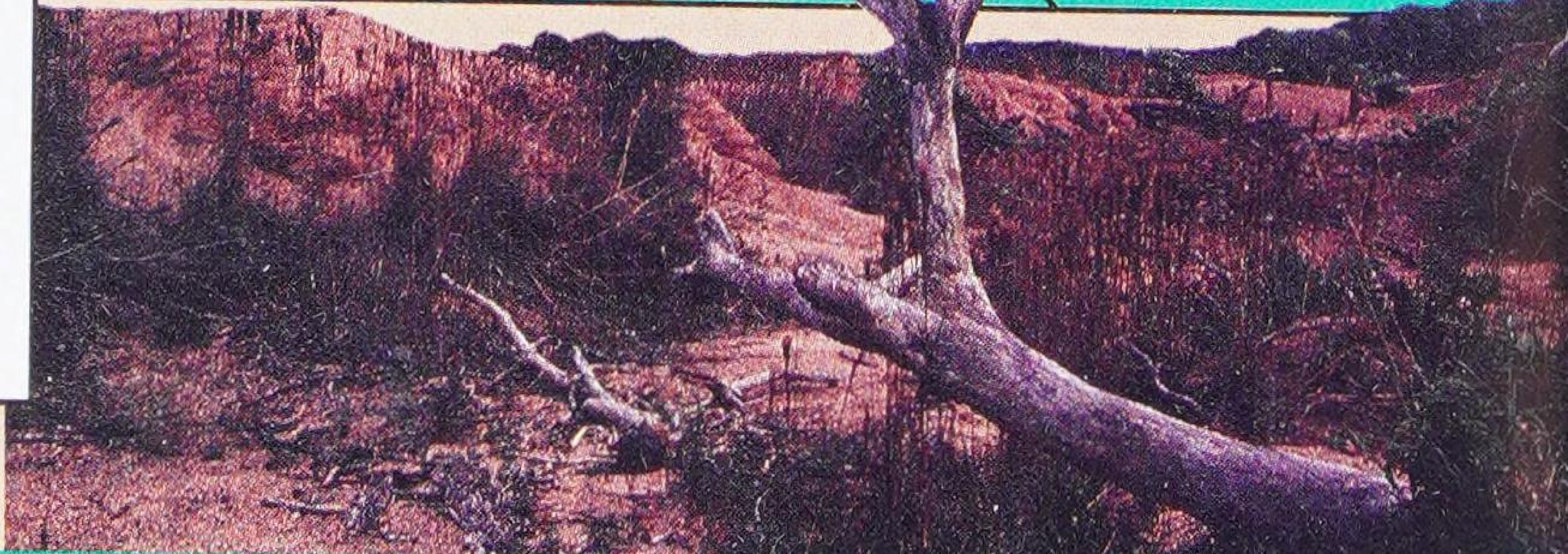
Prince William Sound in Alaska received nearly 11 million gallons of oil when the *Exxon Valdez* ripped apart on the rocks. When and how the sea life of this area restores itself is still unknown. How can oil spills be prevented?

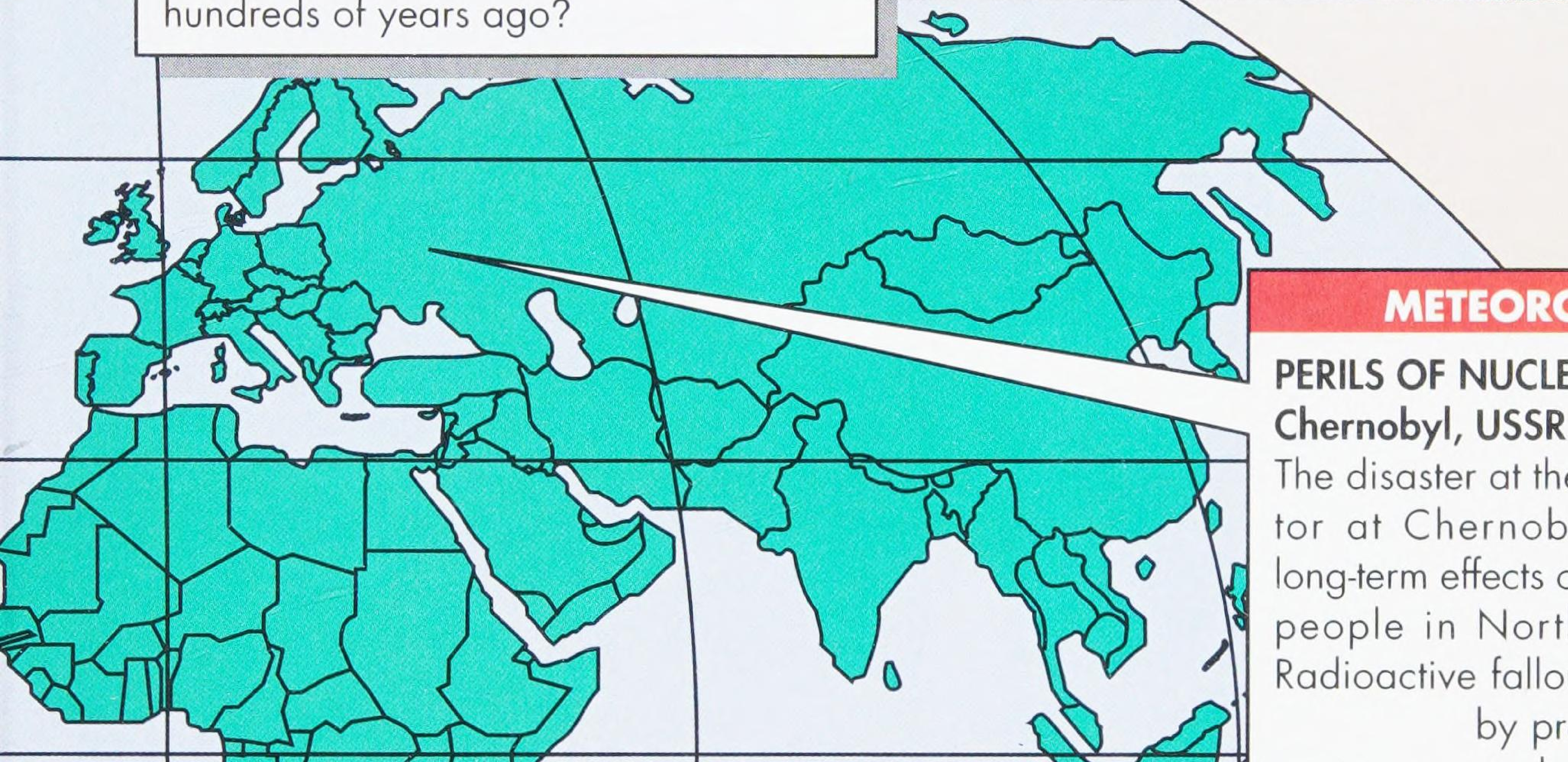
SOCIAL STUDIES

DECLINE OF THE RAIN FOREST

Amazon Basin, Brazil

Rain forests throughout the world are endangered, especially those in Brazil. Brazil is developing some of its rain forest land for farms and mining. How might the Brazilian government protect some of the rain forest?





HISTORY

ANCIENT WEATHER BURIED IN ICE CAP

Greenland

Greenland, the world's largest island, is capped by an immense ice field two miles thick. Climatologists from all over the world study the layers of ice to learn about the weather in ancient times. Why would it be important to know about the climate hundreds of years ago?

METEOROLOGY

PERILS OF NUCLEAR FALLOUT

Chernobyl, USSR

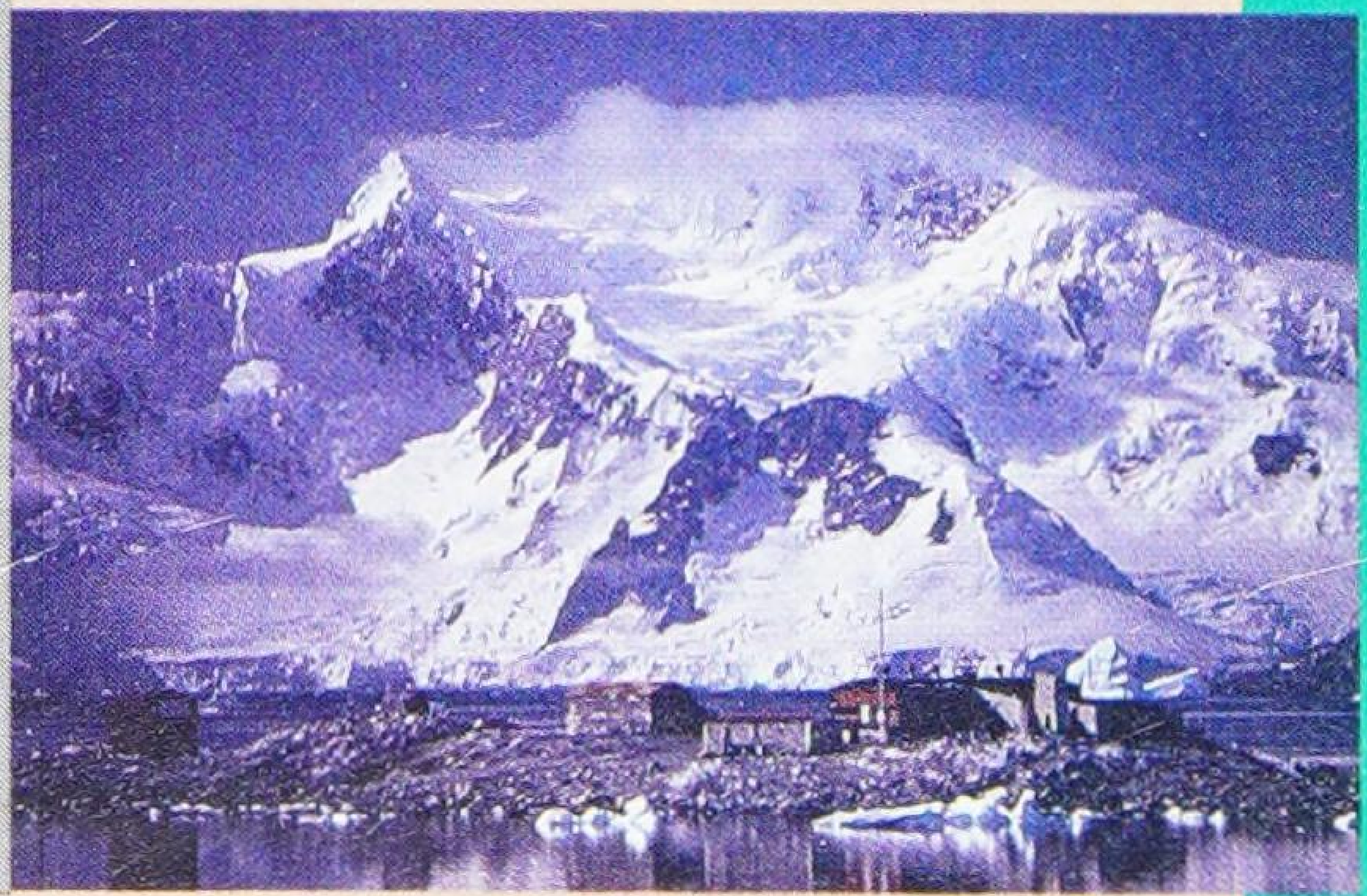
The disaster at the nuclear reactor at Chernobyl may have long-term effects on the health of people in Northern Europe. Radioactive fallout was carried by prevailing winds and picked up by Swedish monitoring stations soon after the tragedy occurred. Should all nuclear plants be required to undergo international inspection?

CHEMISTRY

A HOLE IN THE OZONE LAYER

Antarctica

Scientists studying the ozone layer over the South Pole have noticed an expanding hole in the layer. If it continues, incidence of skin cancer could rise. Why is the ozone layer so important to life on Earth?



CAREERS

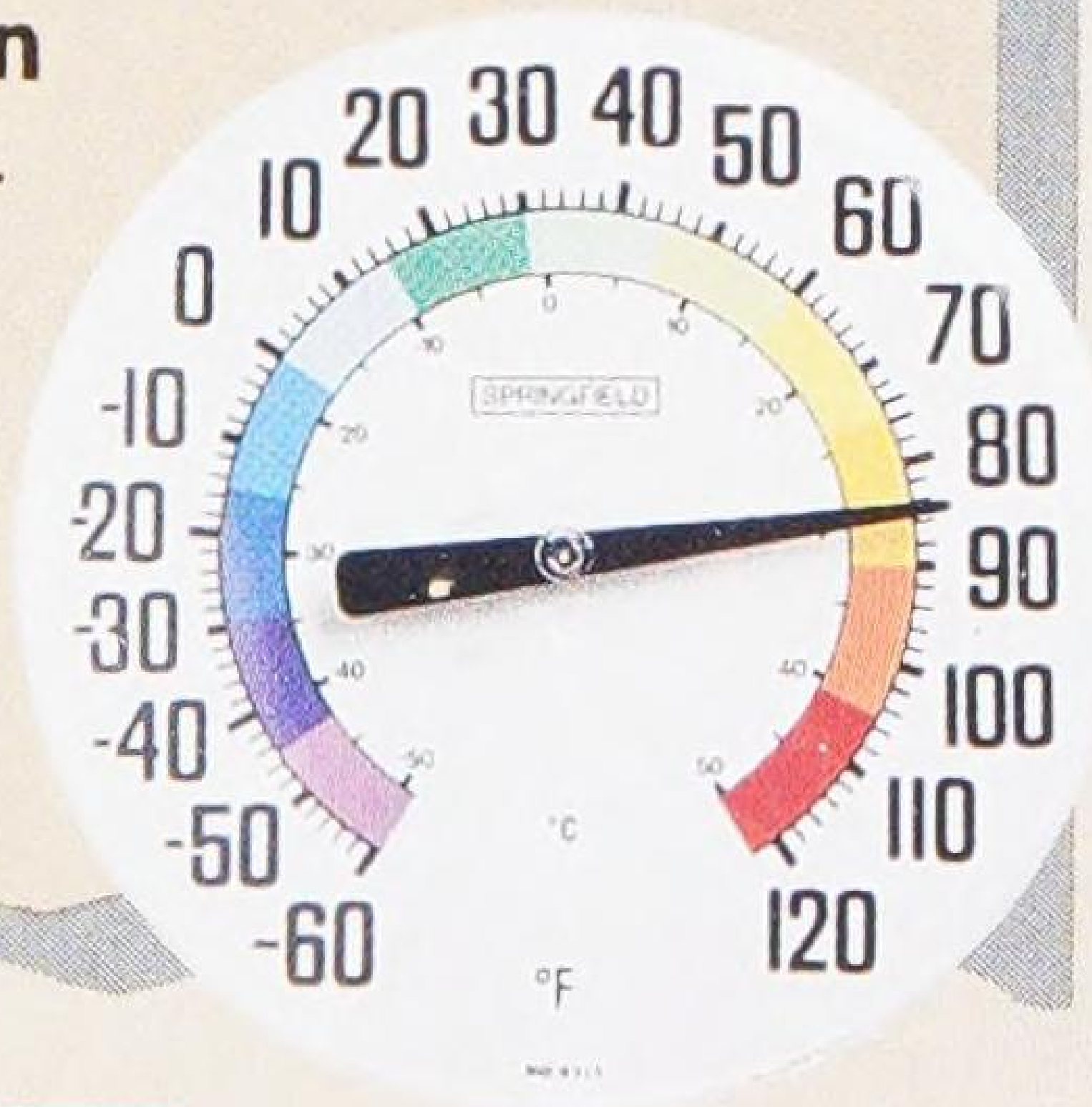
ENVIRONMENTAL ENGINEER

Environmental engineers apply the theories of science and mathematics to solve real environmental problems. They may design special equipment to study ocean depths or probe outer space. A bachelor's degree in engineering is needed for beginning engineering jobs. Environmental engineering is a new technology and requires a degree in engineering, with environmental concerns as a specialty.

Students interested in environmental engineering should take courses in math and science. They will also need to have a knowledge of environmental problems. They may work for a state or federal environmental agency, for a water purification plant, or for a company that cleans up environmental accidents.

For Additional Information

Contact JETS-Guidance, 1420 King St., Suite 405, Alexandria, VA 22314.



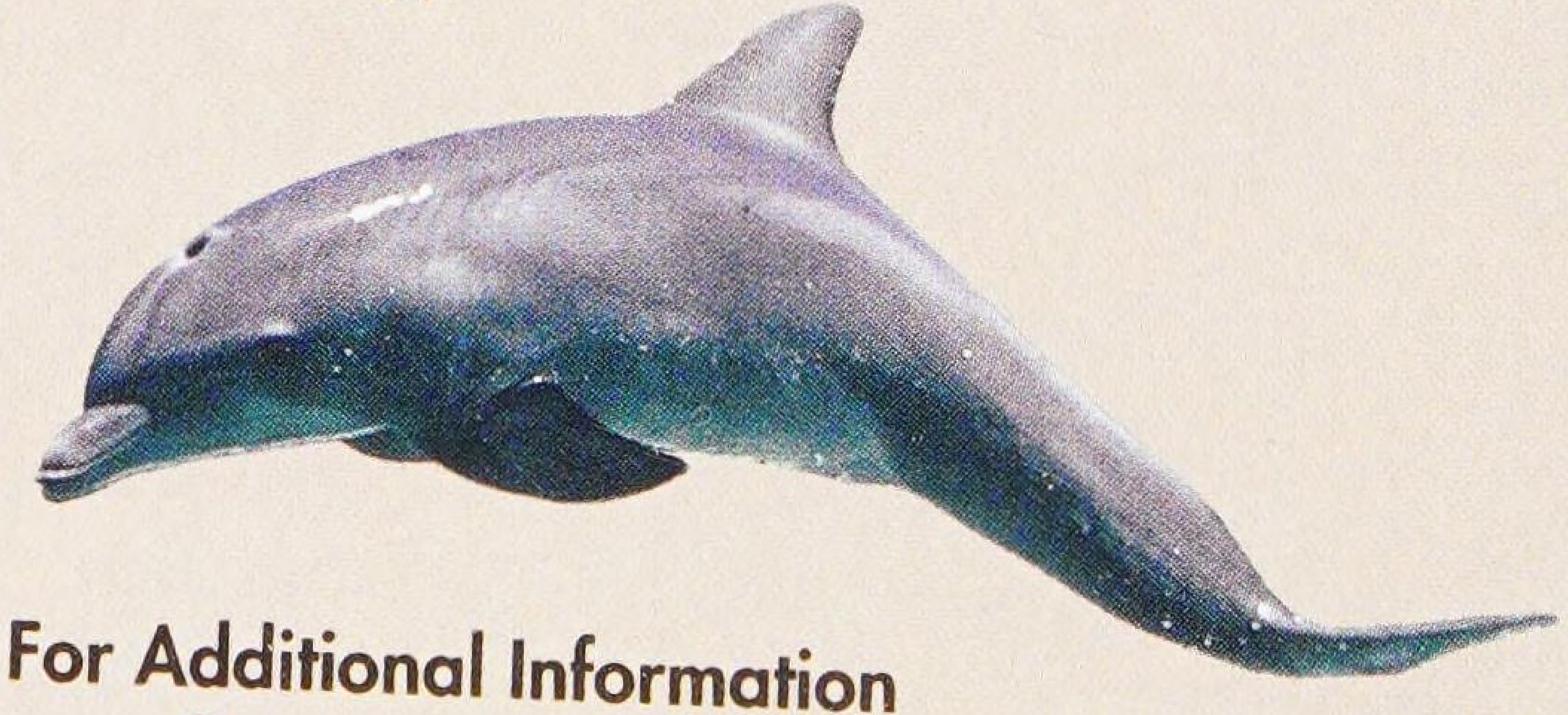
UNIT READINGS

- ▶Carson, Rachel. *Silent Spring*. New York: Macmillan, 1969.
- ▶Grove, Noel. "Air: An Atmosphere of Uncertainty." *National Geographic*, April 1987.
- ▶Stover, Dawn. "Inside Biosphere." *Popular Science*, November 1990.

MARINE ANIMAL TRAINER

As marine parks have become more popular, the need for people to train, exhibit, and care for the animal performers has increased. Dolphins, killer whales, and seals don't naturally perform tricks. These wild animals must be taught how to perform, a task that can take months.

A person who wants to become a *marine animal trainer* should have an interest in animals and their behavior. Most animal trainers learn on-the-job as apprentices. They should have at least a high school diploma with credits in biology.



For Additional Information

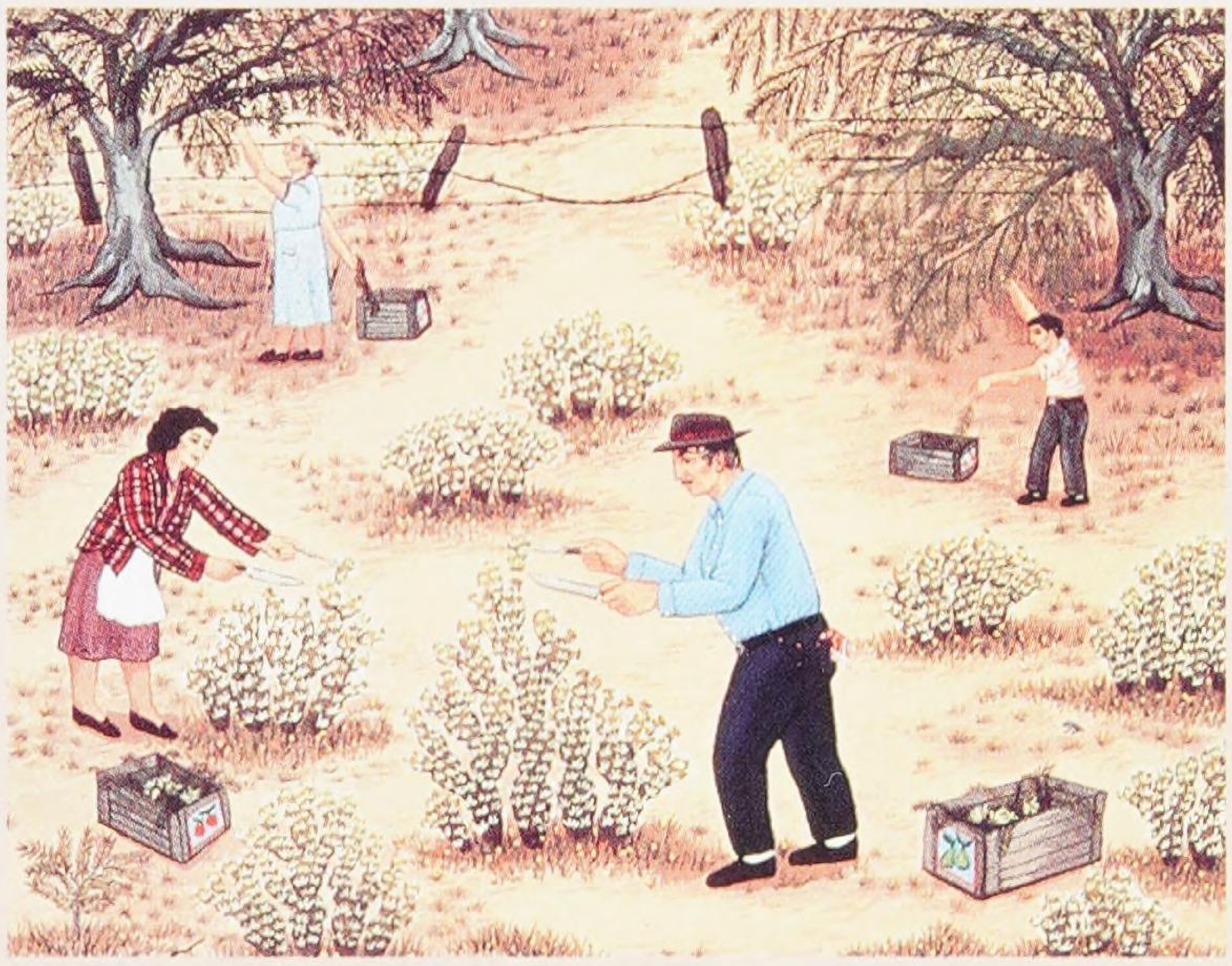
Contact the International Marine Animals Trainer Association, Brookfield Zoo, Brookfield, IL 60513.

Abuelitos Piscando Napolitos

(Grandparents Picking Prickly Pears)

by Carmen Lomas Garzas

The painting, *Abuelitos Piscando Napolitos,* shows the harvest of prickly pear cactus fruits, which are used in Southwestern cooking. The artist, Carmen Lomas Garza, grew up in Kingsville, Texas. The painting is one of several works that represent Garza's response to the Latino movement. The artist wanted to show the culture of Mexican-Americans "in fine art form," as well as portraying the things that are important, beautiful, and moving to the culture. In painting these pictures, she has said that she wished to portray events that are meaningful to all Mexican-American culture.



From the picture, what can you tell about the climate of this area? The prickly pear cactus is common in the American Southwest. A number of desert animals, including the pack rat, use prickly pear cacti for food and a source of water.

Spines on cacti take the place of leaves and help to discourage predators. The fleshy pads that make up the prickly pear and other cacti are actually stems whose spongy tissues hold moisture. In the brief rainy season, these stems expand quickly as the cactus' shallow, but extensive, roots absorb the rainfall.

A number of desert animals use the spiny cacti to protect themselves. The jumping cholla (choy-yuh) cactus has stems that break off at the slightest touch. Large animals find it very unpleasant. But cactus wrens prefer to nest in chollas because they use the cholla stems to protect the entrance to their burrows.

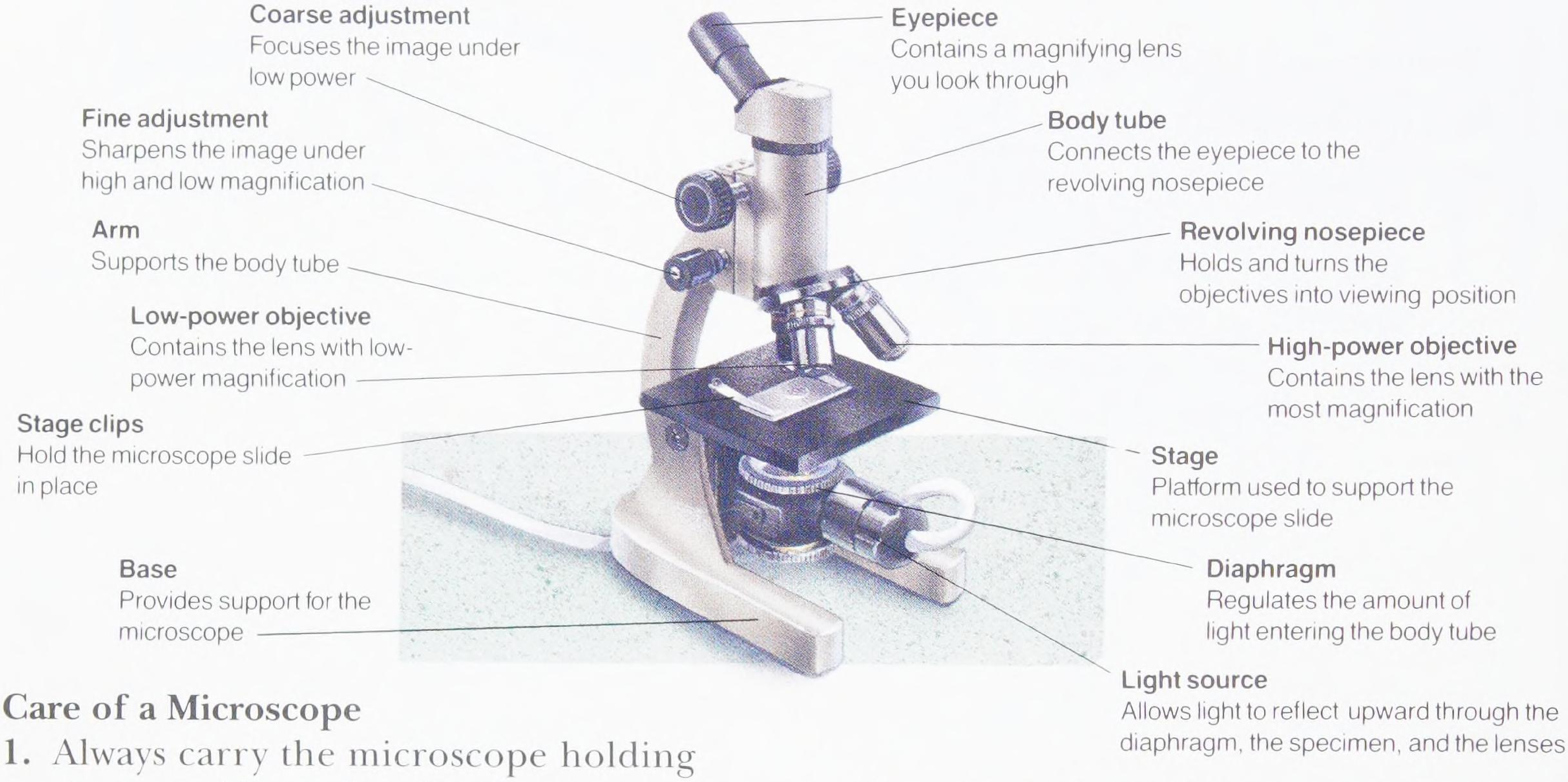
Carmen Garza inherited her talent from her grandmother who was a skilled needleworker and from her mother, a self-taught artist. As a teenager, she decided to become an artist. Choosing this career was a challenge to the traditional role most Hispanic women follow.

In Your Own Words

- Think of an area near where you live that you and your family enjoy. It might be picnic area, a public garden, or a park. Draw a picture of the place and write a paragraph on how it relates to the ecology of the area in which you live.

APPENDIX A

Care and Use of a Microscope


Coarse adjustment
Focuses the image under low power
Fine adjustment
Sharpens the image under high and low magnification
Arm
Supports the body tube
Low-power objective
Contains the lens with low-power magnification
Stage clips
Hold the microscope slide in place
Base
Provides support for the microscope
Eyepiece
Contains a magnifying lens you look through
Body tube
Connects the eyepiece to the revolving nosepiece
Revolving nosepiece
Holds and turns the objectives into viewing position
High-power objective
Contains the lens with the most magnification
Stage
Platform used to support the microscope slide
Diaphragm
Regulates the amount of light entering the body tube
Light source
Allows light to reflect upward through the diaphragm, the specimen, and the lenses

Care of a Microscope

1. Always carry the microscope holding the arm with one hand and supporting the base with the other hand.
2. Don't touch the lenses with your finger.
3. Never lower the coarse adjustment knob when looking through the eyepiece lens.
4. Always focus first with the low-power objective.
5. Don't use the coarse adjustment knob when the high-power objective is in place.
6. Store the microscope covered.

Using a Microscope

1. Place the microscope on a flat surface that is clear of objects. The arm should be toward you.
2. Look through the eyepiece. Adjust the diaphragm so that light comes through the opening in the stage.
3. Place a slide on the stage so that the specimen is in the field of view. Hold it firmly in place by using the stage clips.
4. Always focus first with the coarse adjustment and the low-power objective lens. Once the object is in focus on low power, turn the nosepiece until the high-power objective is in place. Use ONLY the fine adjustment to focus with this lens.

Making a Wet Mount Slide

1. Carefully place the item you want to look at in the center of a clean glass slide. Make sure the sample is thin enough for light to pass through.
2. Use a dropper to place one or two drops of water on the sample.
3. Hold a clean coverslip by the edges and place it at one edge of the drop of water. Slowly lower the coverslip onto the drop of water until it lies flat.
4. If you have too much water or a lot of air bubbles, touch the edge of a paper towel to the edge of the coverslip to draw off extra water and force air out.

APPENDIX B

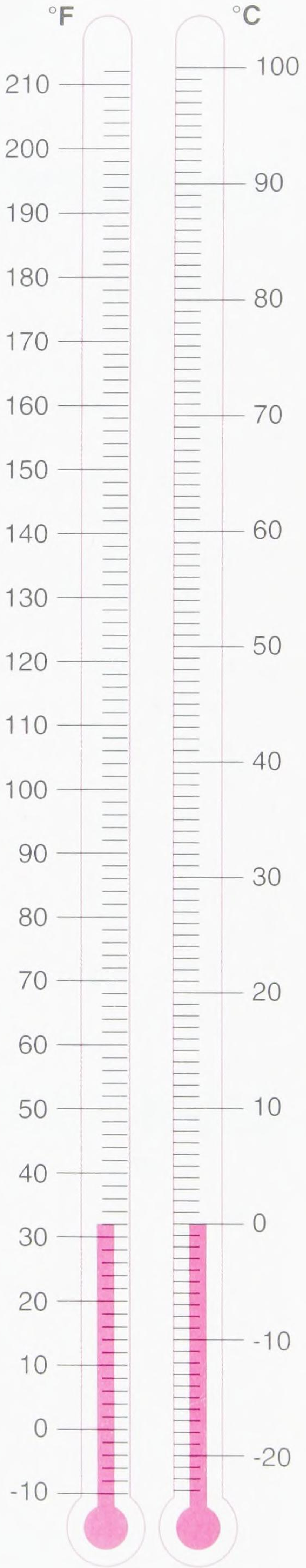


Table B-1

SI/METRIC TO ENGLISH CONVERSIONS

	When you want to convert:	Multiply by:	To find:
Length	inches	2.54	centimeters
	centimeters	0.39	inches
	feet	0.30	meters
	meters	3.28	feet
	yards	0.91	meters
	meters	1.09	yards
	miles	1.61	kilometers
	kilometers	0.62	miles
Mass and Weight*	ounces	20.33	grams
	grams	0.04	ounces
	pounds	0.45	kilograms
	kilograms	2.2	pounds
	tons	0.91	tonnes (metric tons)
	tonnes (metric tons)	1.10	tons
	pounds	4.45	newtons
	newtons	0.23	pounds
Volume	cubic inches	16.38	cubic centimeters
	cubic centimeters	0.06	cubic inches
	cubic feet	0.02	cubic meters
	cubic meters	35.3	cubic feet
	liters	1.06	quarts
	liters	0.26	gallons
	gallons	3.78	liters
Area	square inches	6.45	square centimeters
	square centimeters	0.15	square inches
	square feet	0.09	square meters
	square meters	10.76	square feet
	square miles	2.59	square kilometers
	square kilometers	0.39	square miles
	hectares	2.47	acres
	acres	0.40	hectares
Temperature	Fahrenheit	5/9 (°F – 32)	Celsius
	Celsius	9/5 °C + 32	Fahrenheit

*Weight as measured in standard Earth gravity

APPENDIX C

Safety in the Classroom

1. Always obtain your teacher's permission to begin an activity.
2. Study the procedure. If you have questions, ask your teacher. Understand any safety symbols shown.
3. Use the safety equipment provided for you. Goggles and a safety apron should be worn when any investigation calls for using chemicals.
4. When you are heating a test tube, always slant it so the mouth points away from you and others.
5. Never eat or drink in the lab. Never inhale chemicals. Do not taste any substance or draw any material into a tube with your mouth.
6. If you spill any chemical, wash it off immediately with water. Report the spill immediately to your teacher.
7. Know the location and proper use of the fire extinguisher, safety shower, fire blanket, first aid kit, and fire alarm.
8. Keep all materials away from open flames. Tie back long hair.
9. If a fire should break out in the classroom, or if your clothing should catch fire, smother it with the fire blanket or a coat, or get under a safety shower. **NEVER RUN.**
10. Report any accident or injury, no matter how small, to your teacher.

Follow these procedures as you clean up your work area.

1. Turn off the water and gas. Disconnect electrical devices.
2. Return materials to their places.
3. Dispose of chemicals and other materials as directed by your teacher. Place broken glass and solid substances in the proper containers. Never discard materials in the sink.
4. Clean your work area.
5. Wash your hands thoroughly after working in the laboratory.

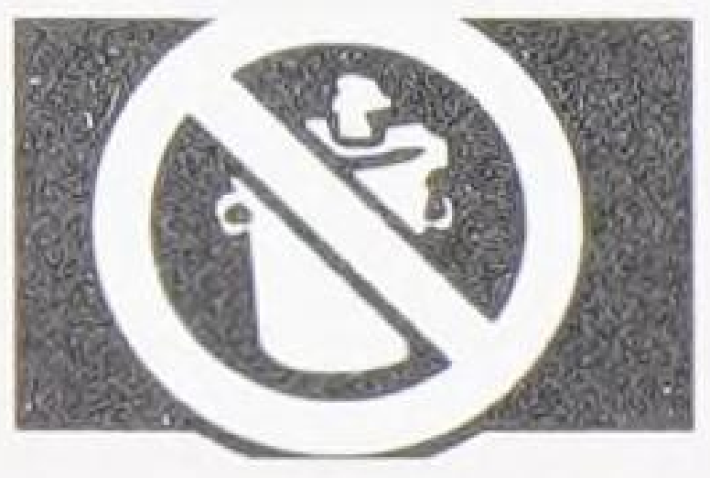
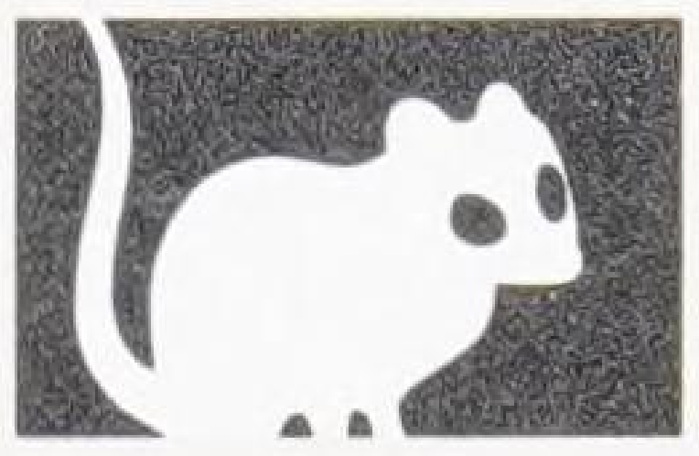
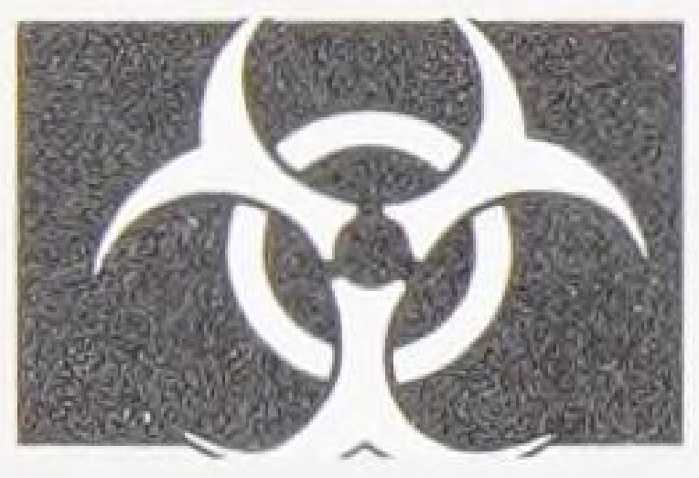
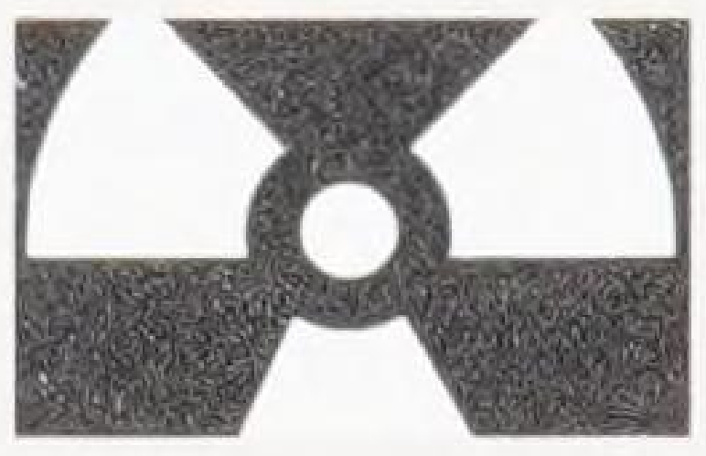
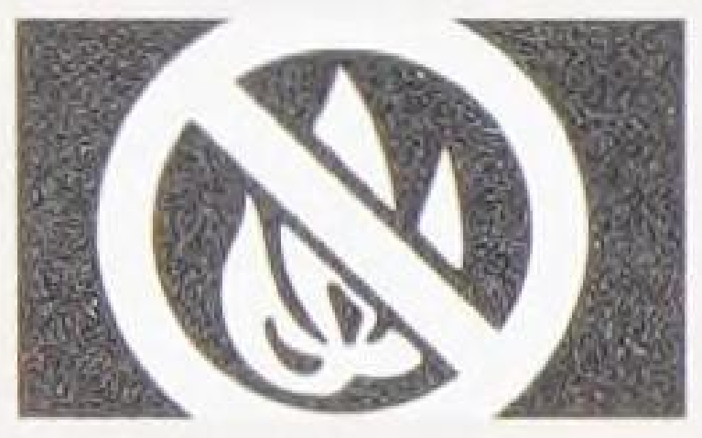
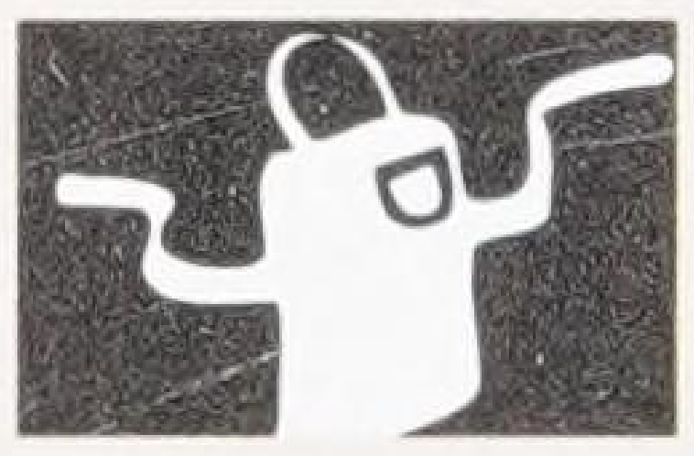
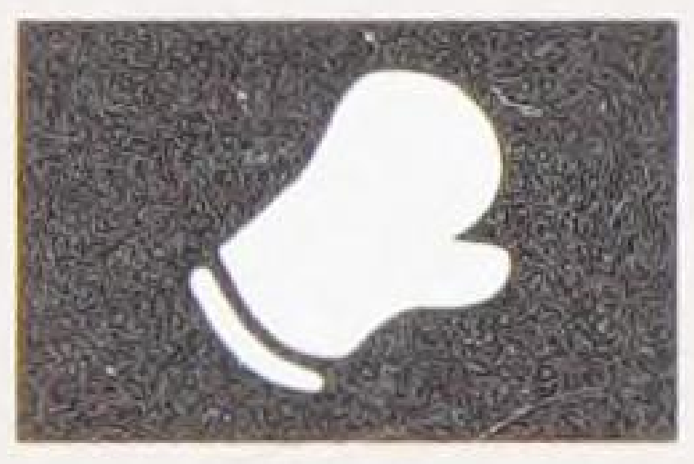
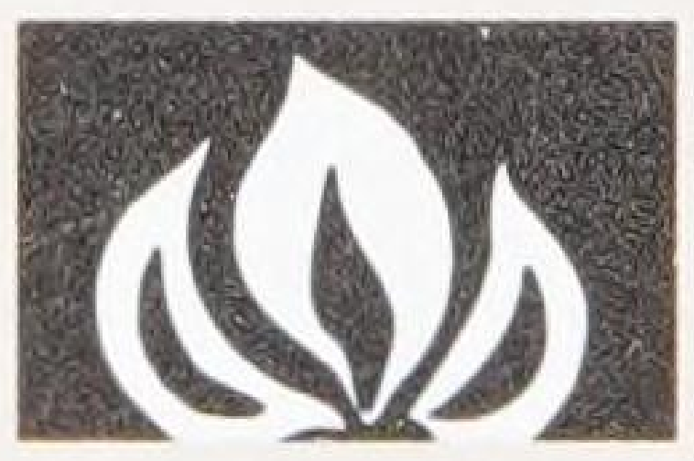
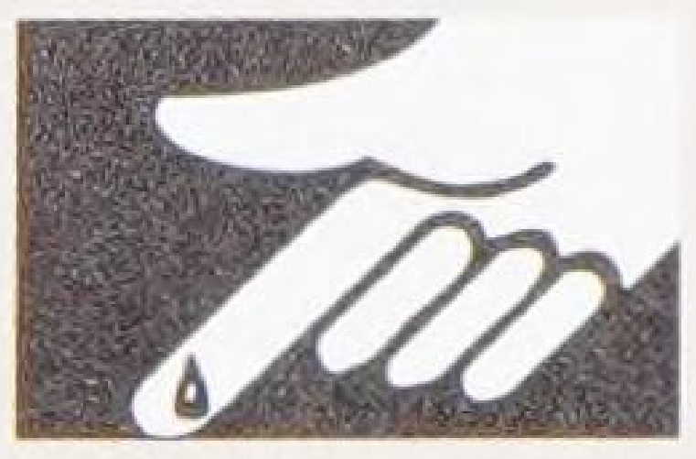
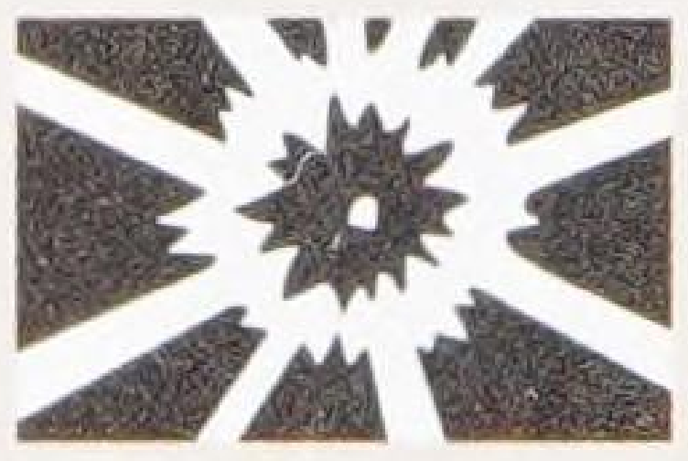
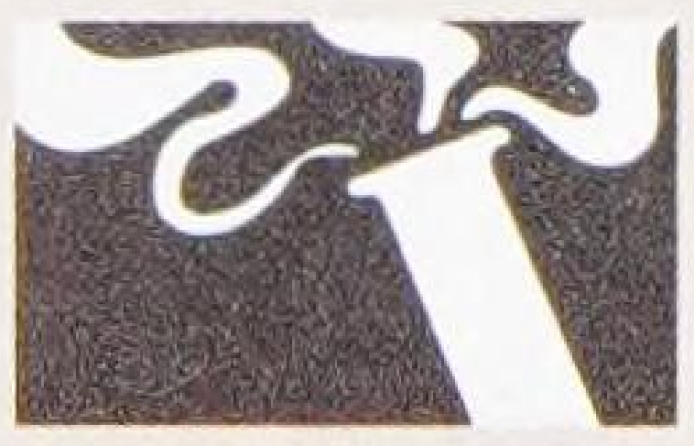
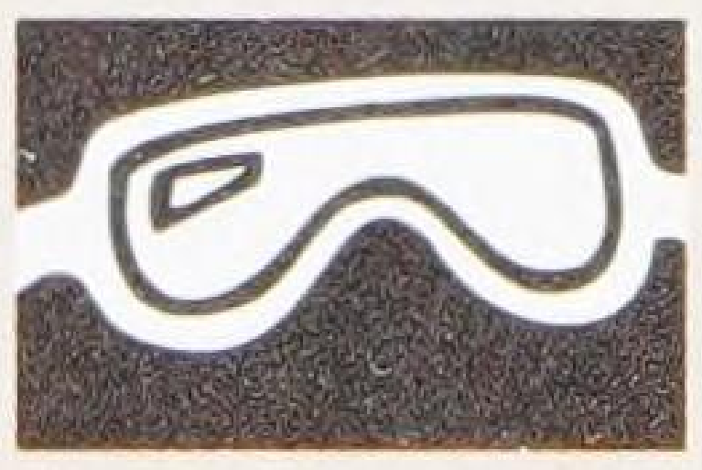
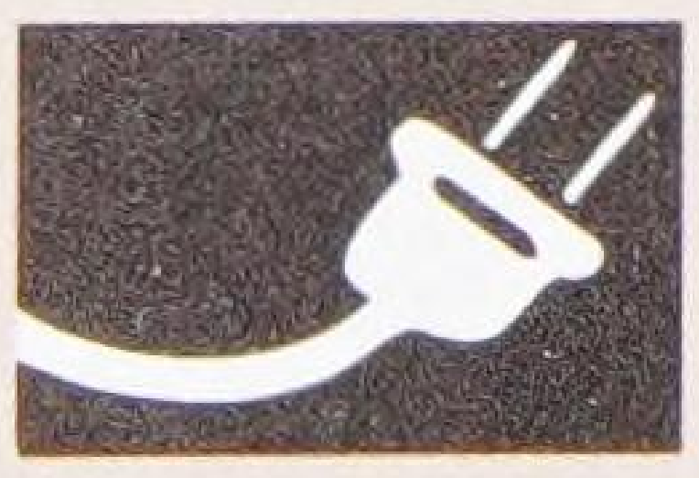
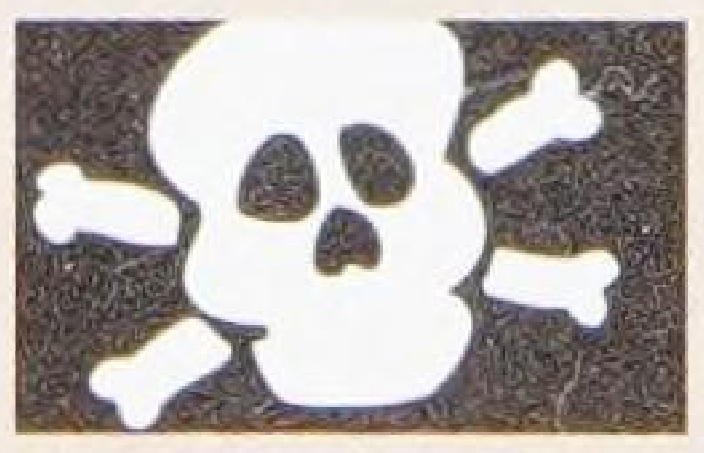
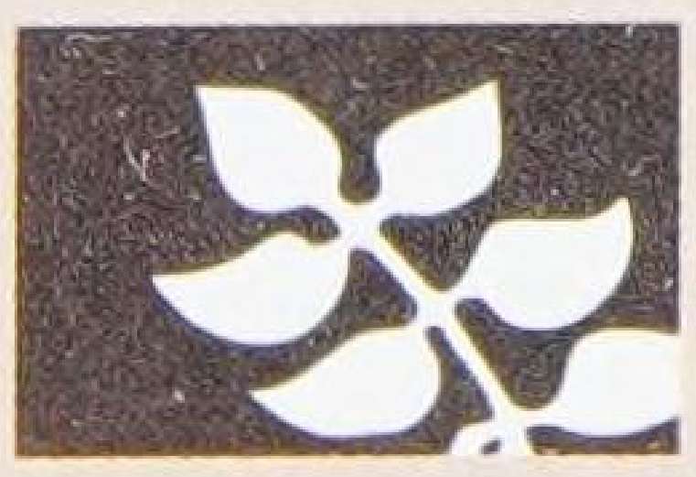
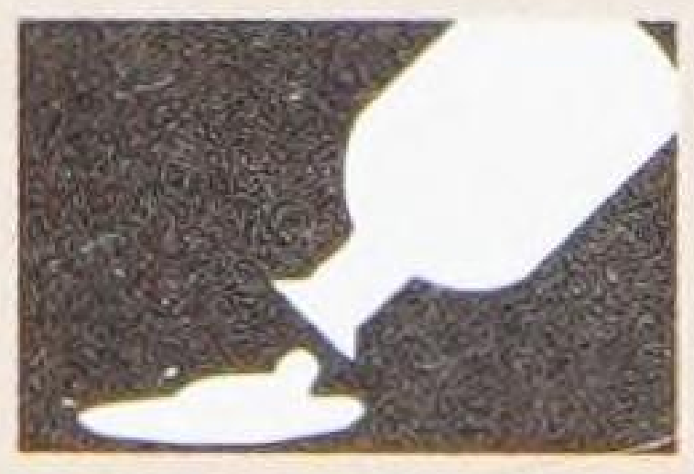
Table C-1

FIRST AID

Injury	Safe response
Burns	Apply cold water. Call your teacher immediately.
Cuts and bruises	Stop any bleeding by applying direct pressure. Cover cuts with a clean dressing. Apply cold compresses to bruises. Call your teacher immediately.
Fainting	Leave the person lying down. Loosen any tight clothing and keep crowds away. Call your teacher immediately.
Foreign matter in eye	Flush with plenty of water. Use eyewash bottle or fountain.
Poisoning	Note the suspected poisoning agent and call your teacher immediately.
Any spills on skin	Flush with large amounts of water or use safety shower. Call your teacher immediately.

SAFETY SYMBOLS

Table C-2

SAFETY SYMBOLS			
	**DISPOSAL ALERT** This symbol appears when care must be taken to dispose of materials properly.		**ANIMAL SAFETY** This symbol appears whenever live animals are studied and the safety of the animals and the students must be ensured.
	**BIOLOGICAL HAZARD** This symbol appears when there is danger involving bacteria, fungi, or protists.		**RADIOACTIVE SAFETY** This symbol appears when radioactive materials are used.
	**OPEN FLAME ALERT** This symbol appears when use of an open flame could cause a fire or an explosion.		**CLOTHING PROTECTION SAFETY** This symbol appears when substances used could stain or burn clothing.
	**THERMAL SAFETY** This symbol appears as a reminder to use caution when handling hot objects.		**FIRE SAFETY** This symbol appears when care should be taken around open flames.
	**SHARP OBJECT SAFETY** This symbol appears when a danger of cuts or punctures caused by the use of sharp objects exists.		**EXPLOSION SAFETY** This symbol appears when the misuse of chemicals could cause an explosion.
	**FUME SAFETY** This symbol appears when chemicals or chemical reactions could cause dangerous fumes.		**EYE SAFETY** This symbol appears when a danger to the eyes exists. Safety goggles should be worn when this symbol appears.
	**ELECTRICAL SAFETY** This symbol appears when care should be taken when using electrical equipment.		**POISON SAFETY** This symbol appears when poisonous substances are used.
	**PLANT SAFETY** This symbol appears when poisonous plants or plants with thorns are handled.		**CHEMICAL SAFETY** This symbol appears when chemicals used can cause burns or are poisonous if absorbed through the skin.

APPENDIX D

Classification

Merrill Life Science uses a five kingdom system of classification. In this system there is one kingdom of organisms that are prokaryotes, organisms that lack a true nucleus and organelles—Kingdom Monera. There are four kingdoms of eukaryotes: Kingdom Protista, Kingdom Fungi, the Plant Kingdom, and the Animal Kingdom.

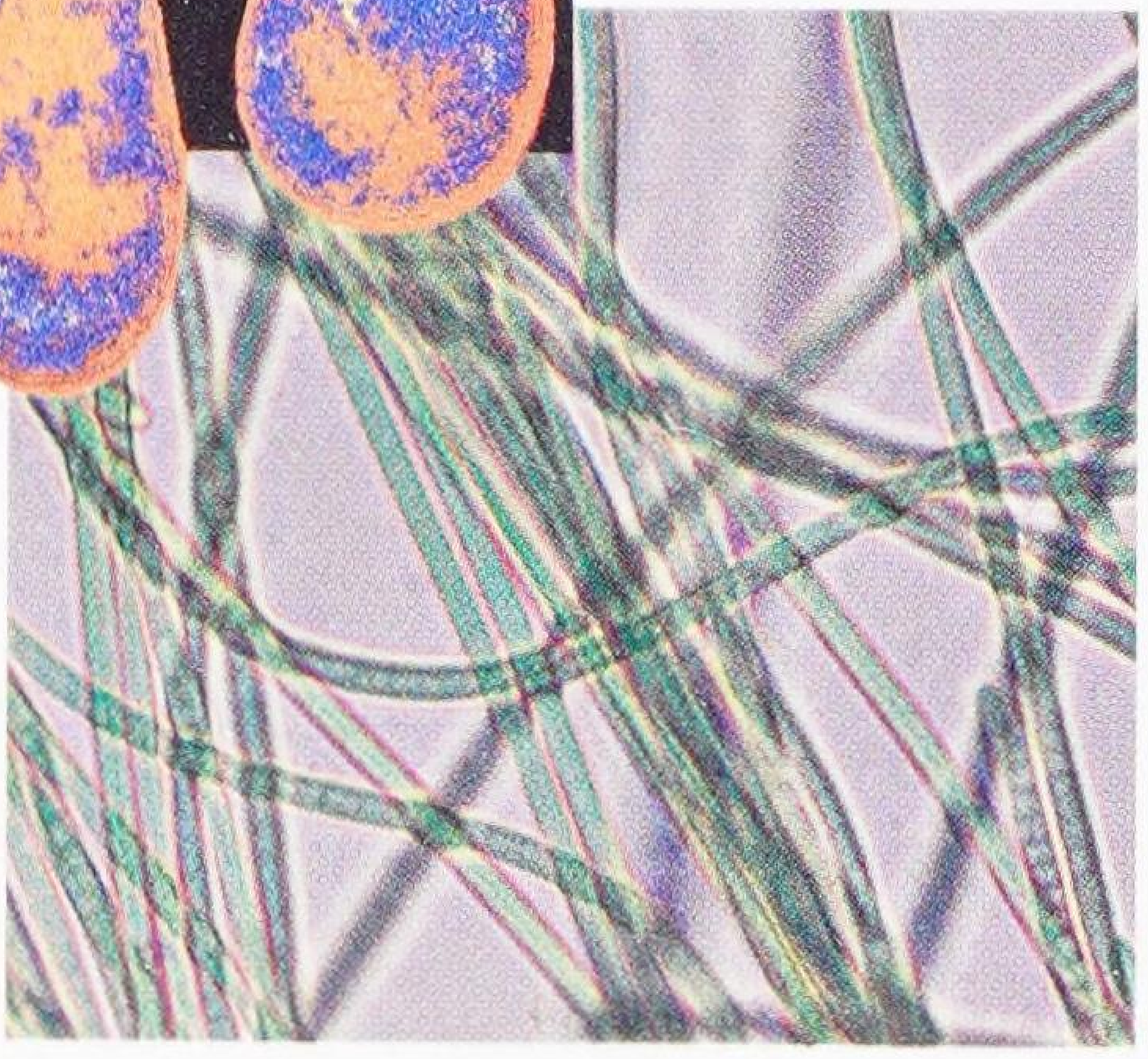
All the phyla and divisions of organisms discussed in this textbook are outlined in this Appendix.

Kingdom Monera

Phylum Cyanobacteria: one-celled prokaryotes; make their own food, contain chlorophyll, some species form colonies, most are blue-green

Bacteria: one-celled prokaryotes; most absorb food from their surroundings, some are photosynthetic; many are parasites; round, spiral, or rod shaped

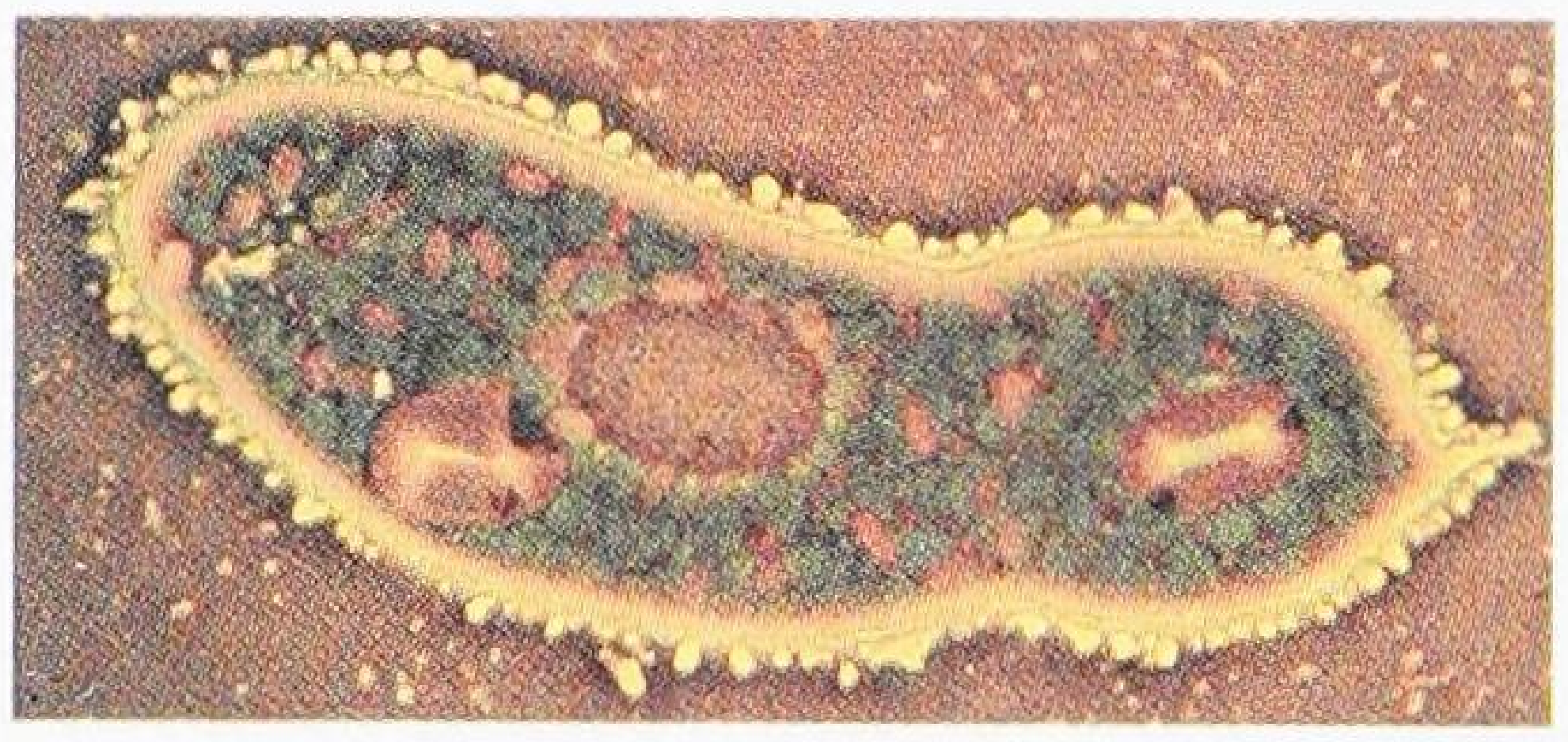
Clostridium botulinum ×13 960



Oscillatoria ×200

Kingdom Protista

Phylum Euglenophyta: one-celled; can photosynthesize or take in food; most have one flagellum

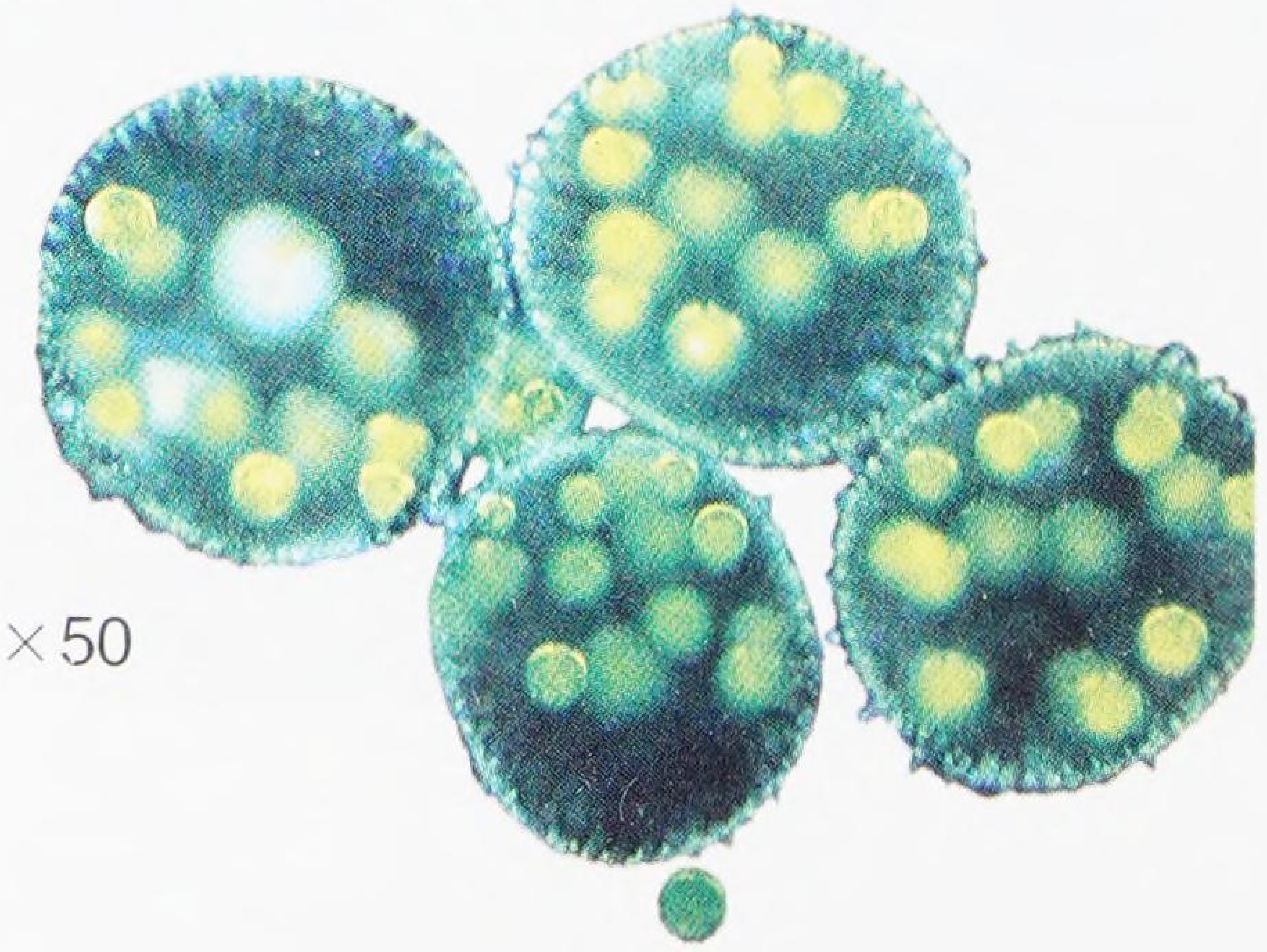


Euglena oxyuris

Phylum Crysophyta: most are one-celled; make their own food through photosynthesis; golden-brown pigments mask chlorophyll; diatoms

Phylum Pyrrophyta: one-celled; make their own food through photosynthesis; contain red pigments and have two flagella; dinoflagellates

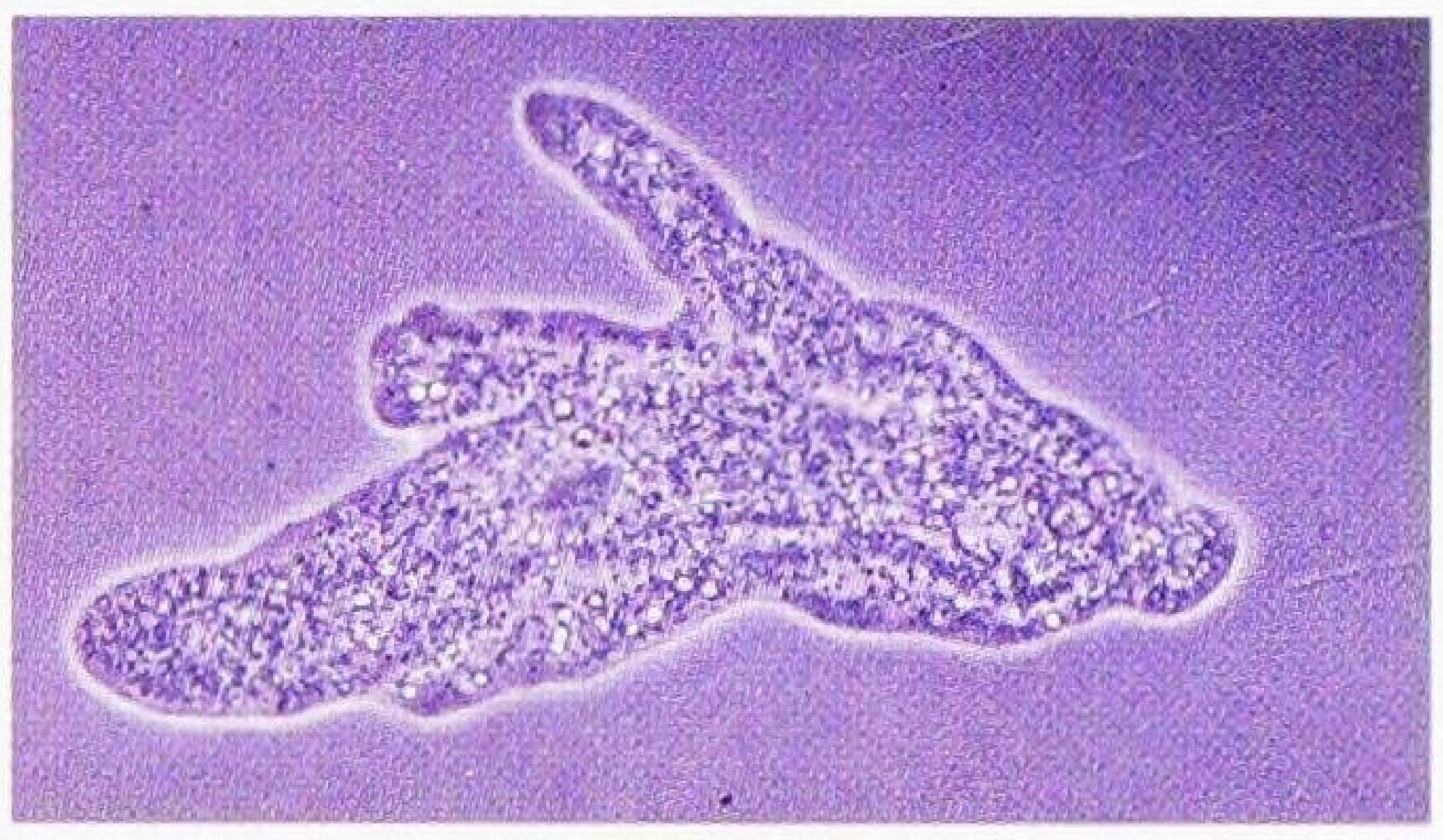
Phylum Chlorophyta: one-celled, many-celled, or colonies; contain chlorophyll and make their own food; live on land, in fresh water or salt water; green algae



Volvox ×50

Phylum Rhodophyta: most are many-celled and photosynthetic; contain red pigments; most live in deep saltwater environments; red algae

Phylum Phaeophyta: most are many-celled and photosynthetic; contain brown pigments; most live in saltwater environments; brown algae


Amoeba discoides

Phylum Sarcodina: one-celled; take in food; move by means of pseudopods; free-living or parasitic; sarcodines

Phylum Mastigophora: one-celled; take in food; have two or more flagella; free living or parasitic; flagellates

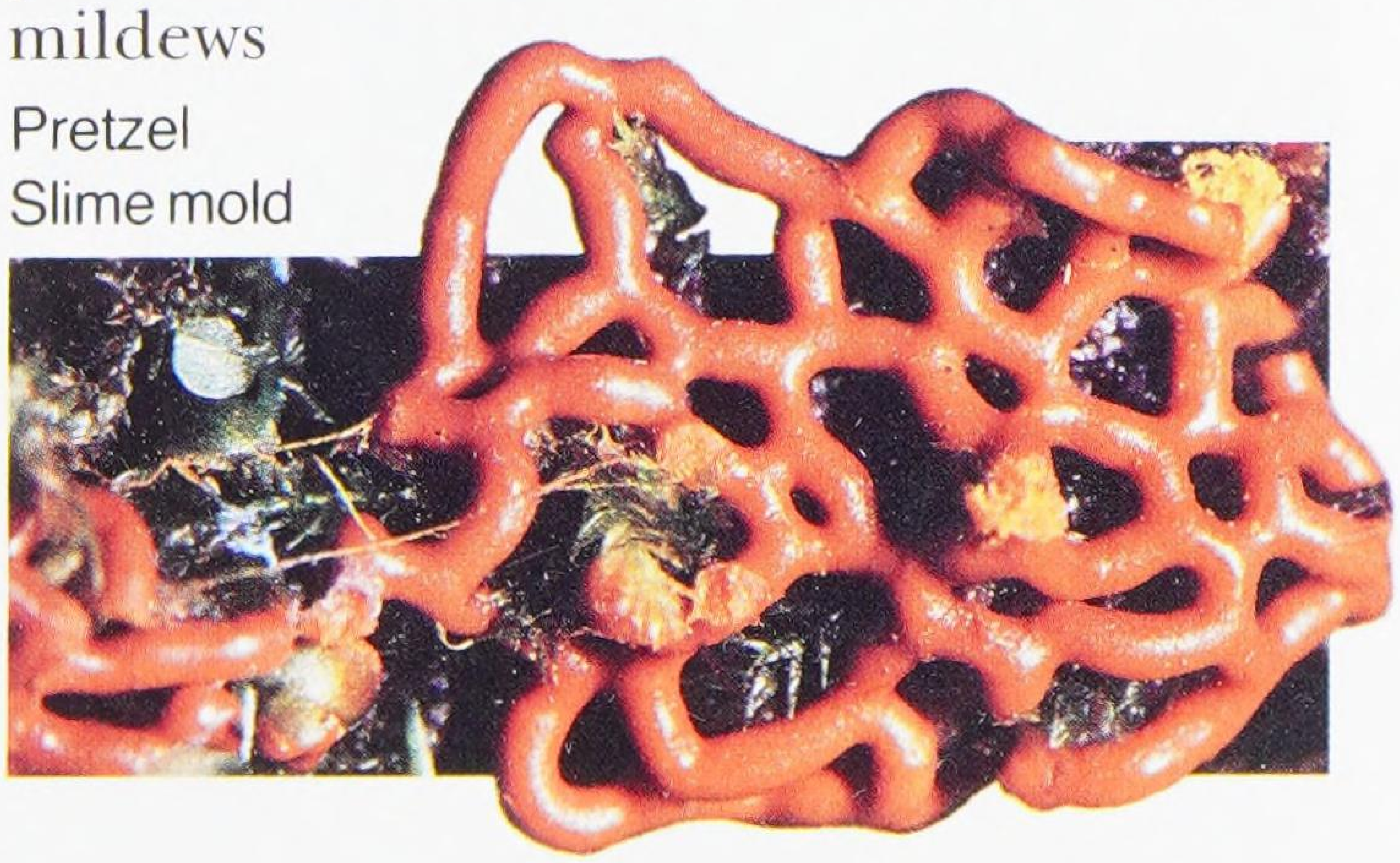
Phylum Ciliophora: one-celled; take in food; have large numbers of cilia; ciliates

Phylum Sporozoa: one-celled; take in food; no means of movement; parasites in animals; sporozoans

Phylum Myxomycetes, Phylum Acrasiomycota: one- or many-celled; absorb food; change form during life cycle; cellular and plasmodial slime molds

Phylum Oomycota: live in water or on land; one- or many-celled parasites; absorb dead organic matter; cause diseases in plants and animals; water molds and mildews

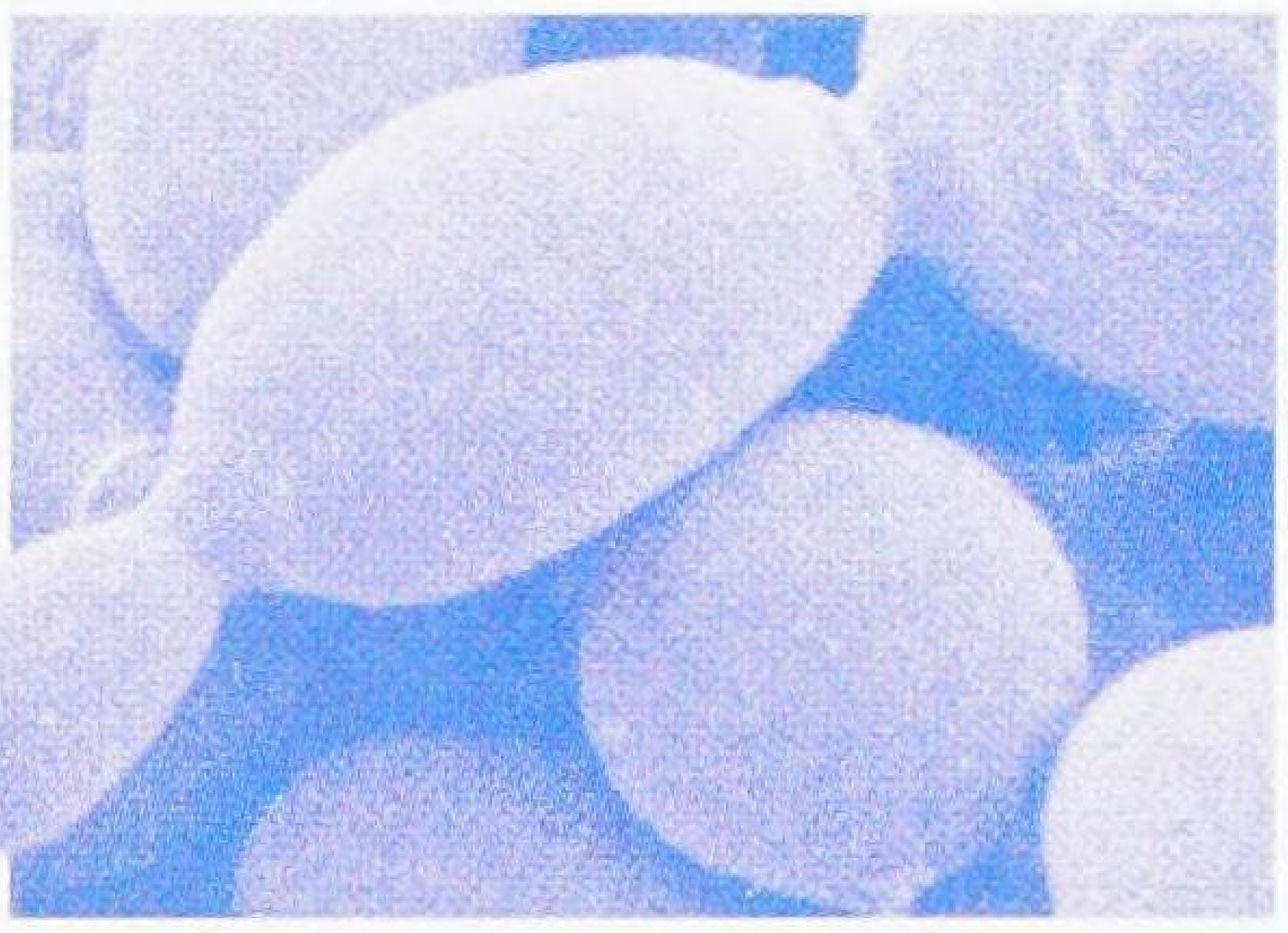
Pretzel Slime mold



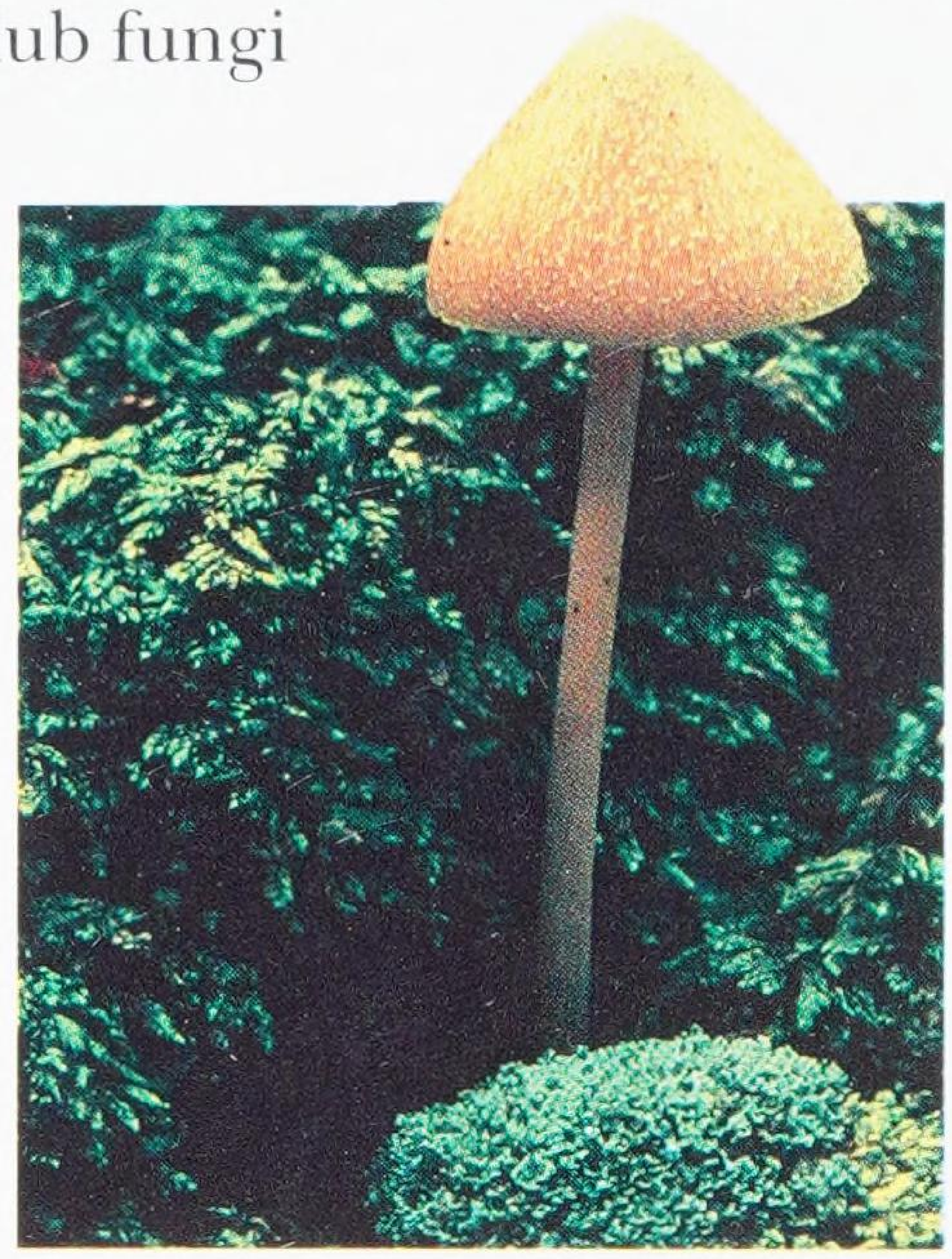
Kingdom Fungi

Division Zygomycota: many-celled; absorb food; spores are produced in sporangia; zygote fungi

Division Ascomycota: one- and many-celled; absorb food; spores produced in asci; sac fungi


Yeast × 7800

Division Basidiomycota: many-celled; absorb food; spores produced in basidia; club fungi


Mushroom

Division Deuteromycota: members with unknown reproductive structures; imperfect fungi

Lichens: organism formed by symbiotic relationship between an ascomycote or a basidiomycote and a green alga or a cyanobacterium; fungus provides protection and the algae or cyanobacterium provides food

Old Man's Beard lichen

Plant Kingdom

Division Bryophyta: non vascular plants that reproduce by spores produced in capsules; many-celled; green; grow in moist land environments; mosses and liverworts

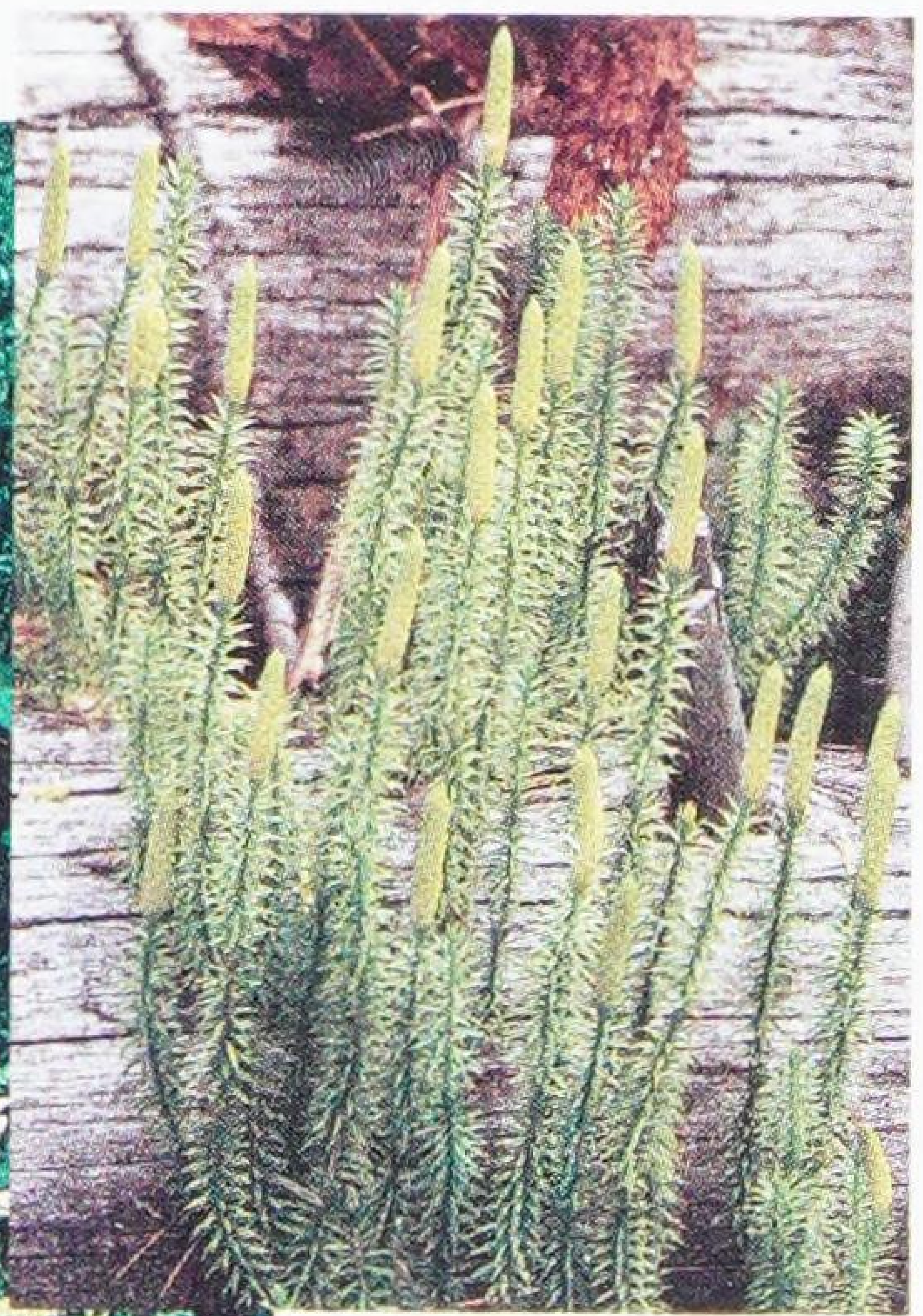
Liverwort

Spore Plants

Division Lycophyta: many-celled vascular plants; spores produced in cones; live on land; are photosynthetic; club mosses

Division Sphenophyta: vascular plants with ribbed and jointed stems; scalelike leaves; spores produced in cones; horsetails

Division Pterophyta: vascular plants with feathery leaves called fronds; spores produced in clusters of sporangia called sori; live on land or in water; ferns



Club moss

Fern

Seed Plants

Division Ginkgophyta: deciduous gymnosperms; only one living species called the maiden hair tree; fan-shaped leaves with branching veins; reproduces with seeds; ginkgos

Division Cycadophyta: palmlike gymnosperms; large compound leaves; produce seeds in cones; cycads

Ginkgo biloba

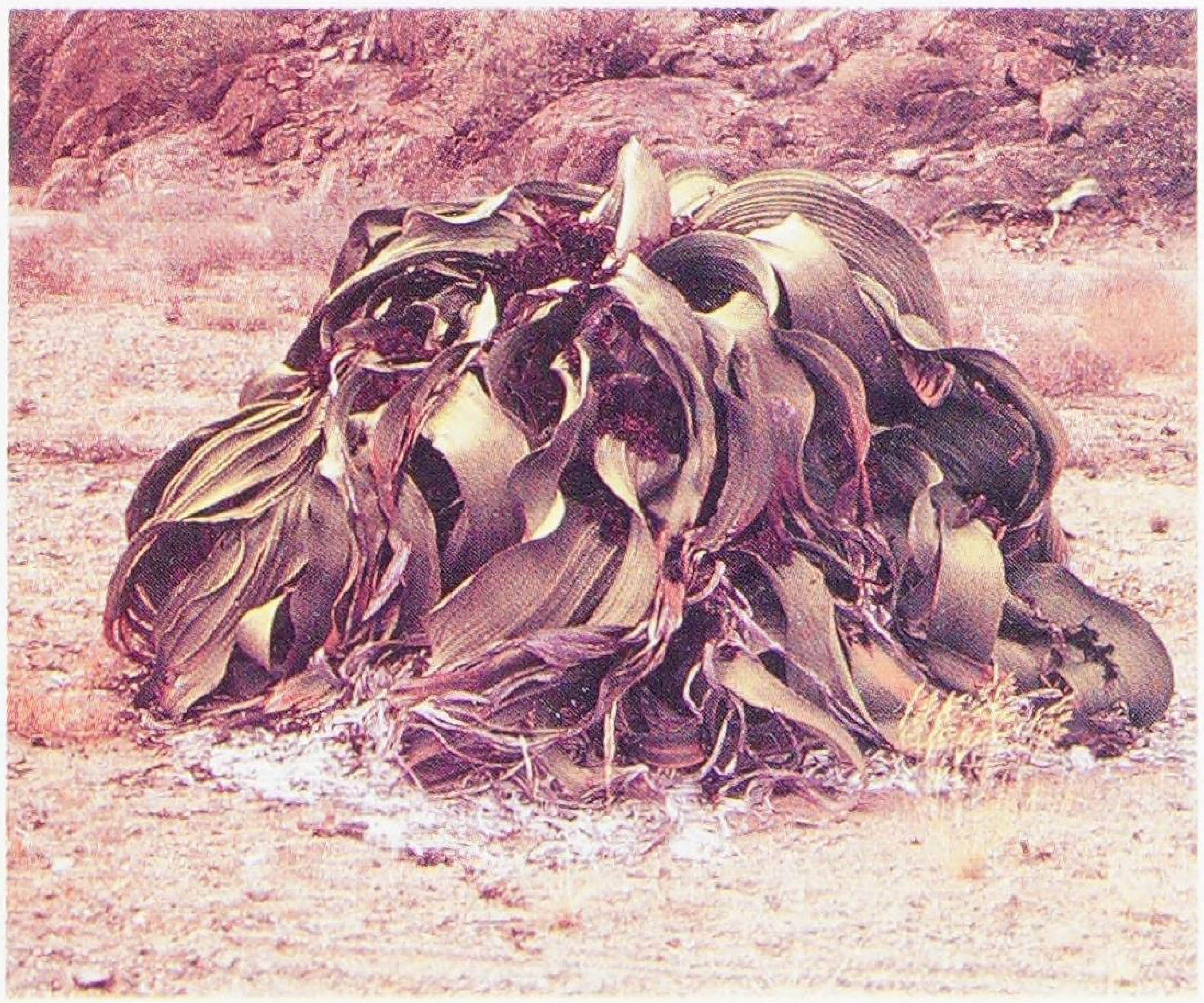
Sago Palm

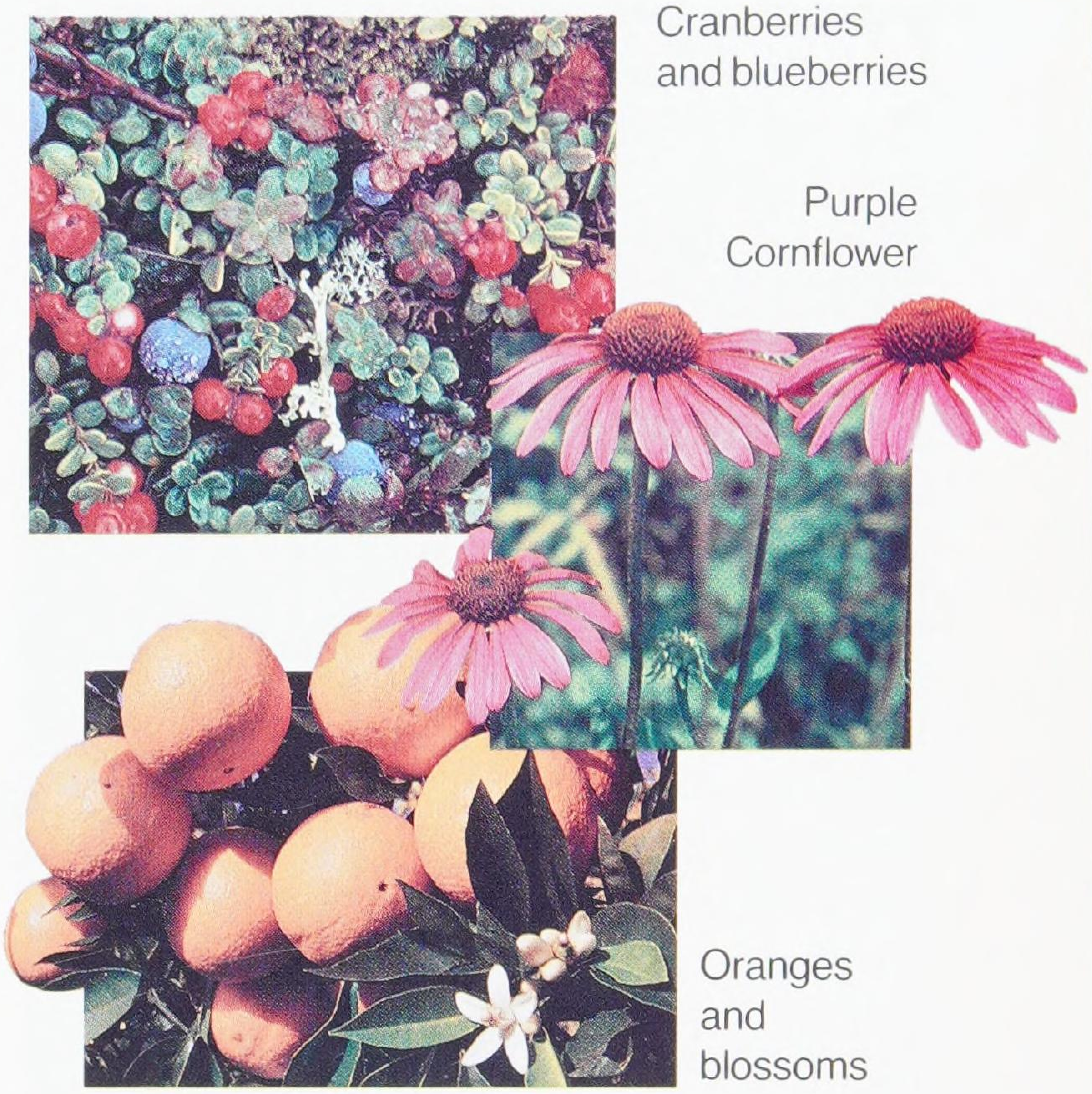
Division Coniferophyta: deciduous or evergreen gymnosperms; trees or shrubs; needlelike or scalelike leaves; seeds produced in cones; conifers

Slash Pine flower

Pine forest, North Yukon, Canada

Division Gnetophyta: shrubs or woody vines; seeds produced in cones; division contains only three genera; gnetum

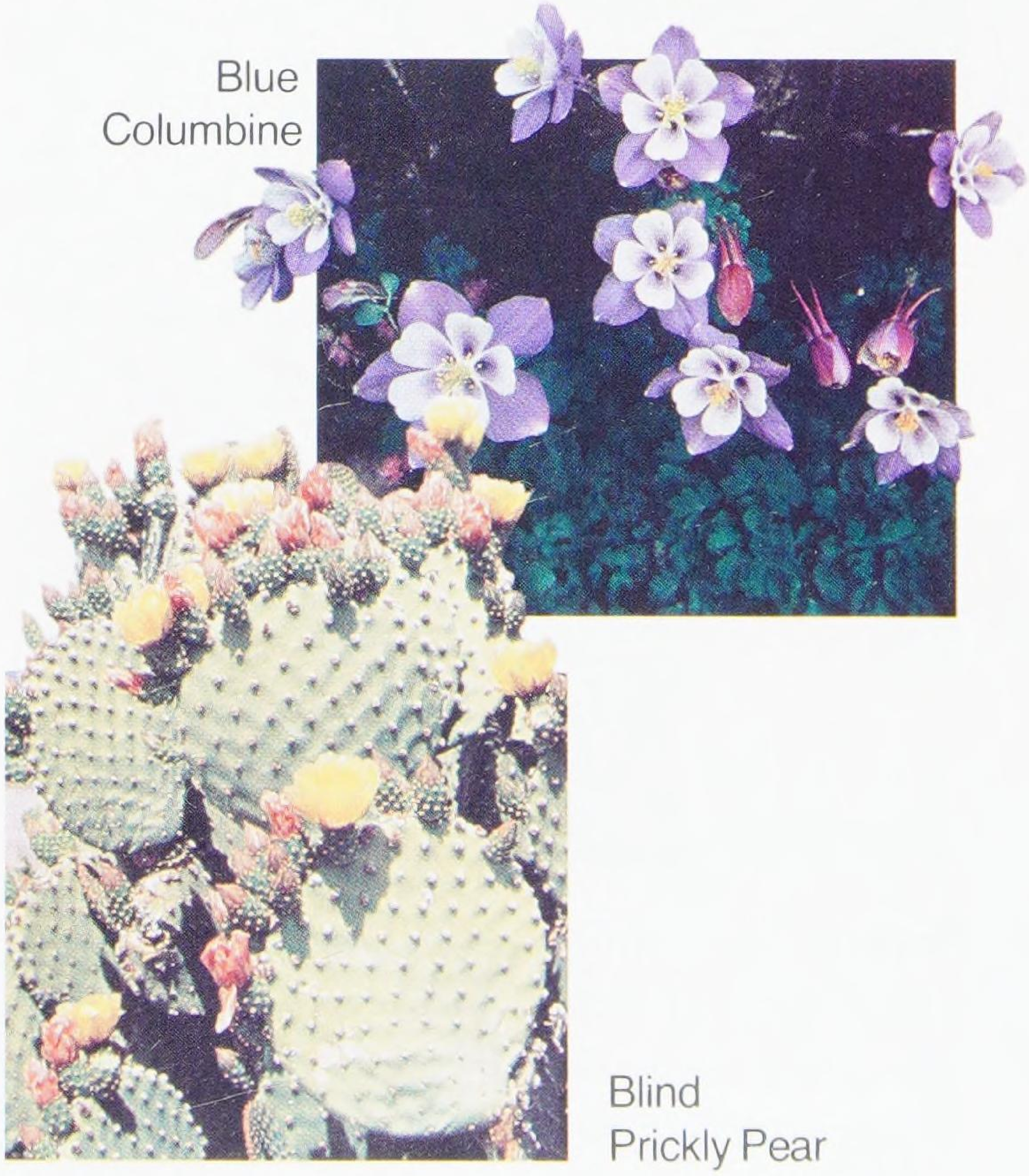

Welwitschia mirabilis


Cranberries and blueberries

Purple Cornflower

Oranges and blossoms

Division Anthophyta: dominant group of plants; ovules protected at fertilization by an ovary; sperm carried to ovules by pollen tube; produce flowers and seeds in fruits; flowering plants

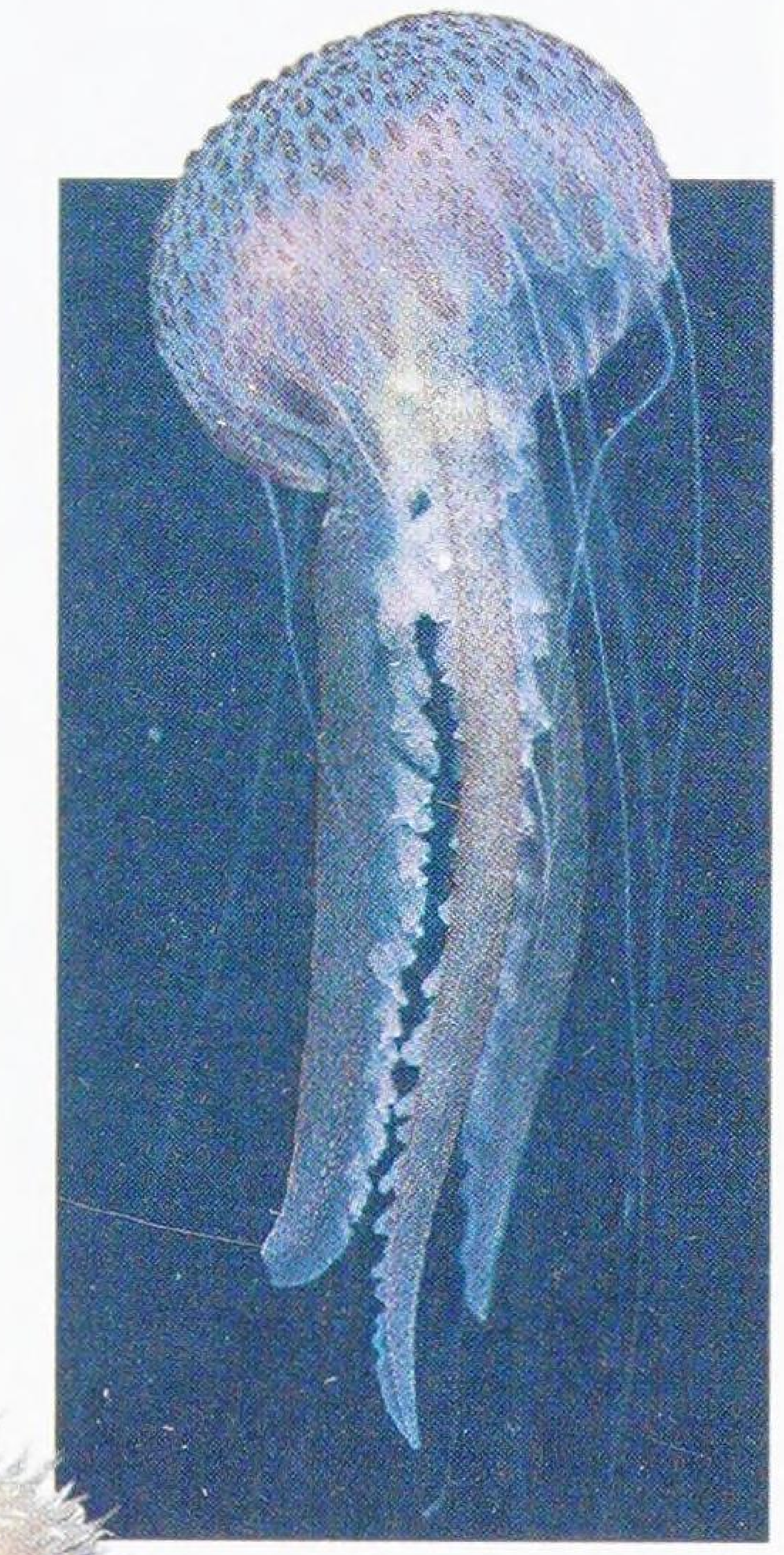

Blue Columbine

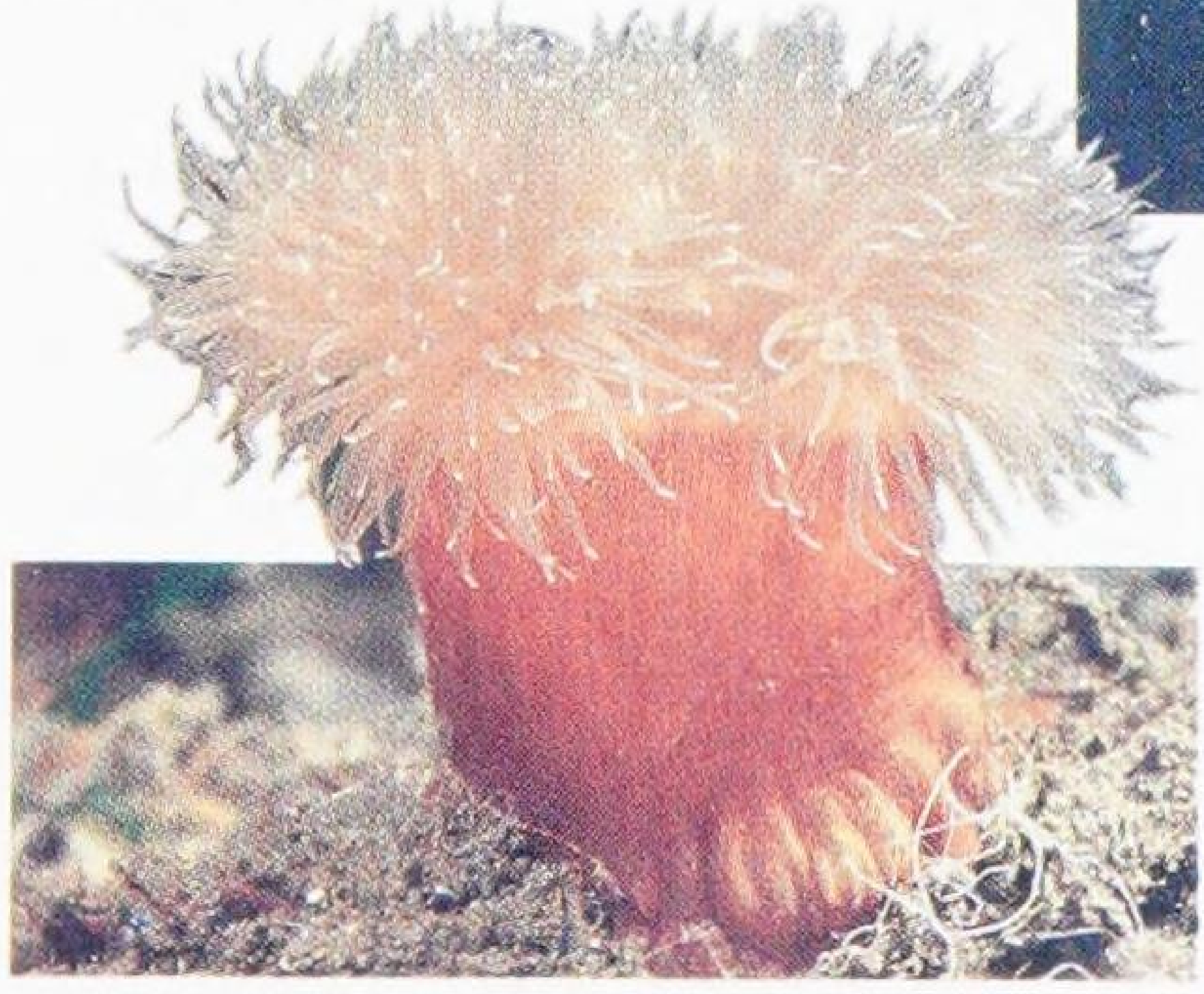
Blind Prickly Pear

Animal Kingdom

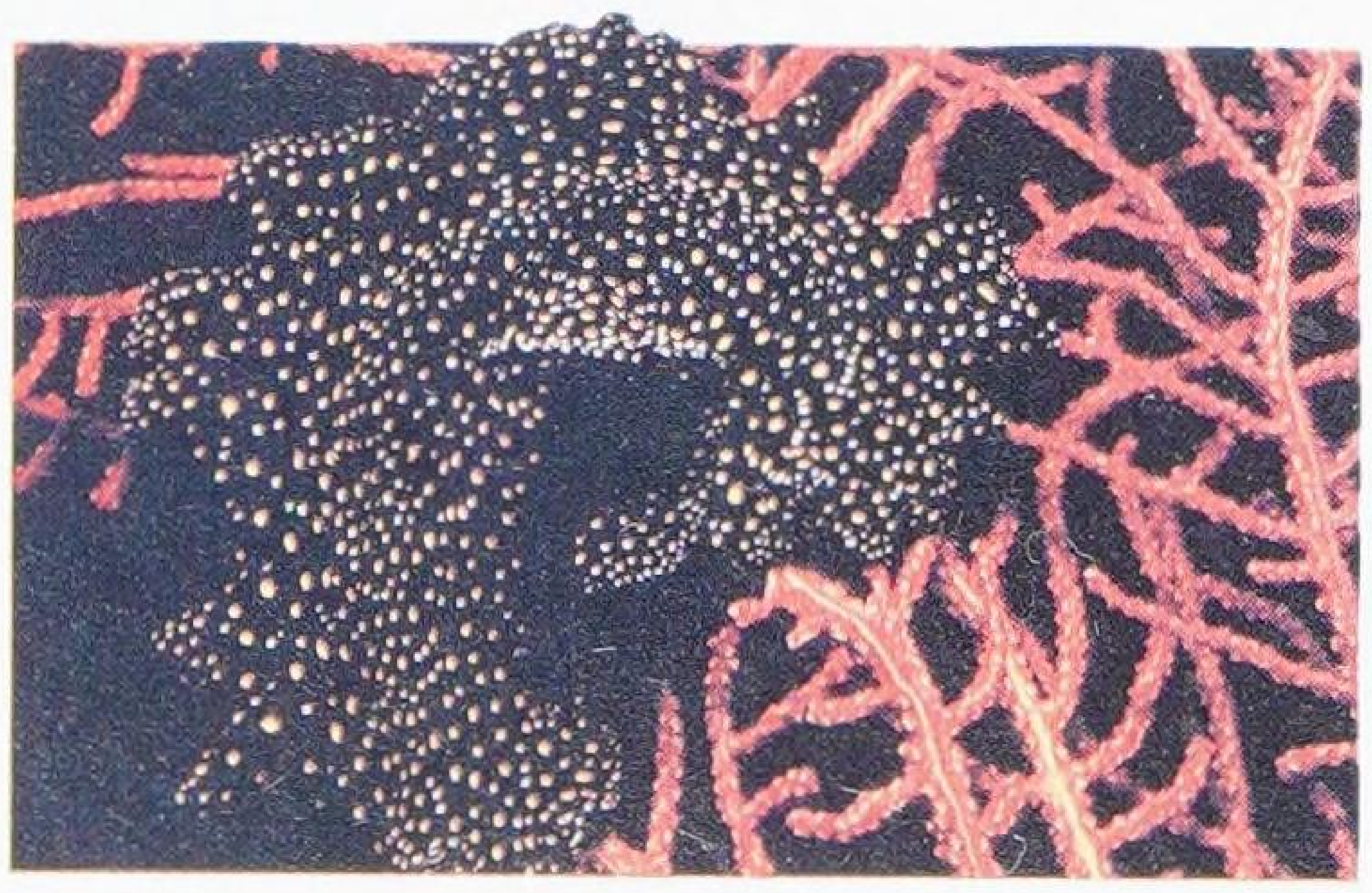
Phylum Porifera: aquatic organisms that lack true tissues and organs; they are asymmetrical and sessile; sponges

Phylum Cnidaria: radially symmetrical organisms with a digestive cavity with one opening; most have tentacles armed with stinging cells; live in aquatic environments singly or in colonies; includes jellyfish, corals, hydra, and sea anemones


Jellyfish


Frilled Anemone

Phylum Platyhelminthes: bilaterally symmetrical worms with flattened bodies; digestive system has one opening; parasitic and free-living species; flatworms


Flatworm

Phylum Nematoda: round bilaterally symmetrical body; digestive system with two openings; some free-living forms but mostly parasitic; roundworms

Phylum Mollusca: soft-bodied animals, many with a hard shell; a mantle covers the soft body; aquatic and terrestrial species; includes clams, snails, squid, and octopuses

Snail

Spanish Shawl Nudibranch

Phylum Annelida: bilaterally symmetrical worms with round segmented bodies; terrestrial and aquatic species; well-developed body systems; includes earthworms, leeches, and marine polychaetes

Christmas Tree worm

Phylum Arthropoda: very large phylum of organisms that have segmented bodies with pairs of jointed appendages, and a hard exoskeleton; terrestrial and aquatic species; includes insects crustaceans, spiders, and horseshoe crabs

Swallowtail butterfly

Sally Light-foot crab

Jumping spider

Phylum Echinodermata: saltwater organisms with spiny or leathery skin; water-vascular system with tube feet; radial symmetry; includes starfish, sand dollars, and sea urchins

Brittle stars

Seahorse

Toucan

Phylum Chordata: organisms with internal skeletons, specialized body systems, and paired appendages; all at some time have a notochord, dorsal nerve cord, gill slits, and a tail; include fish, amphibians, reptiles, birds, and mammals

Peninsula turtles

Mare and foal

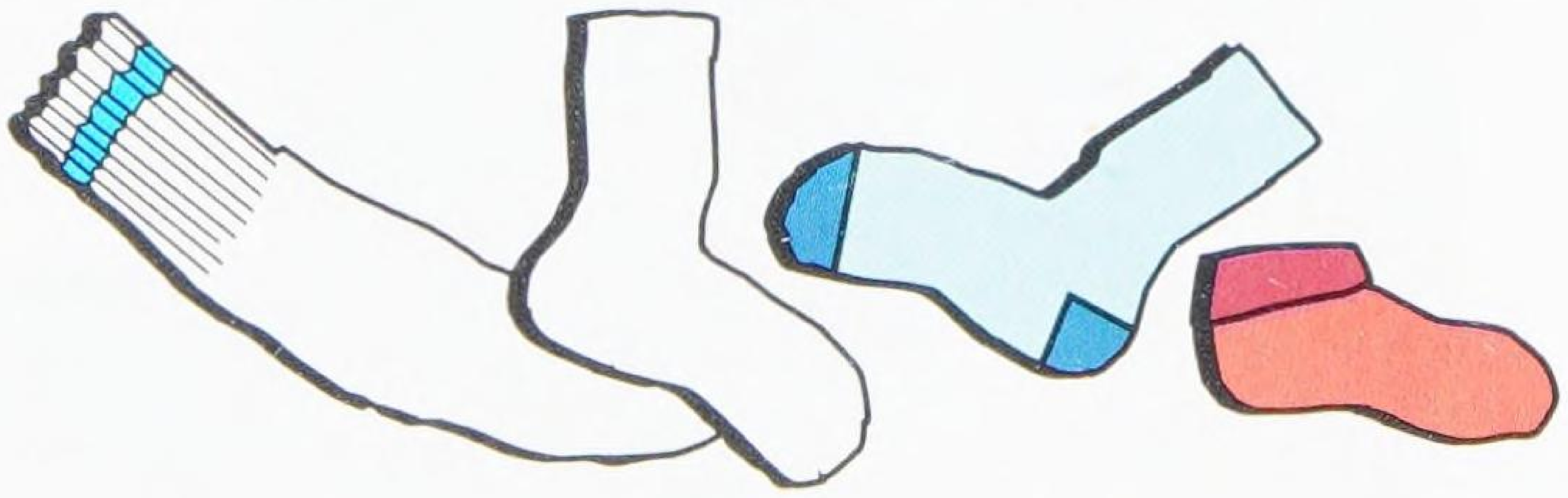
Organizing Information

Classifying

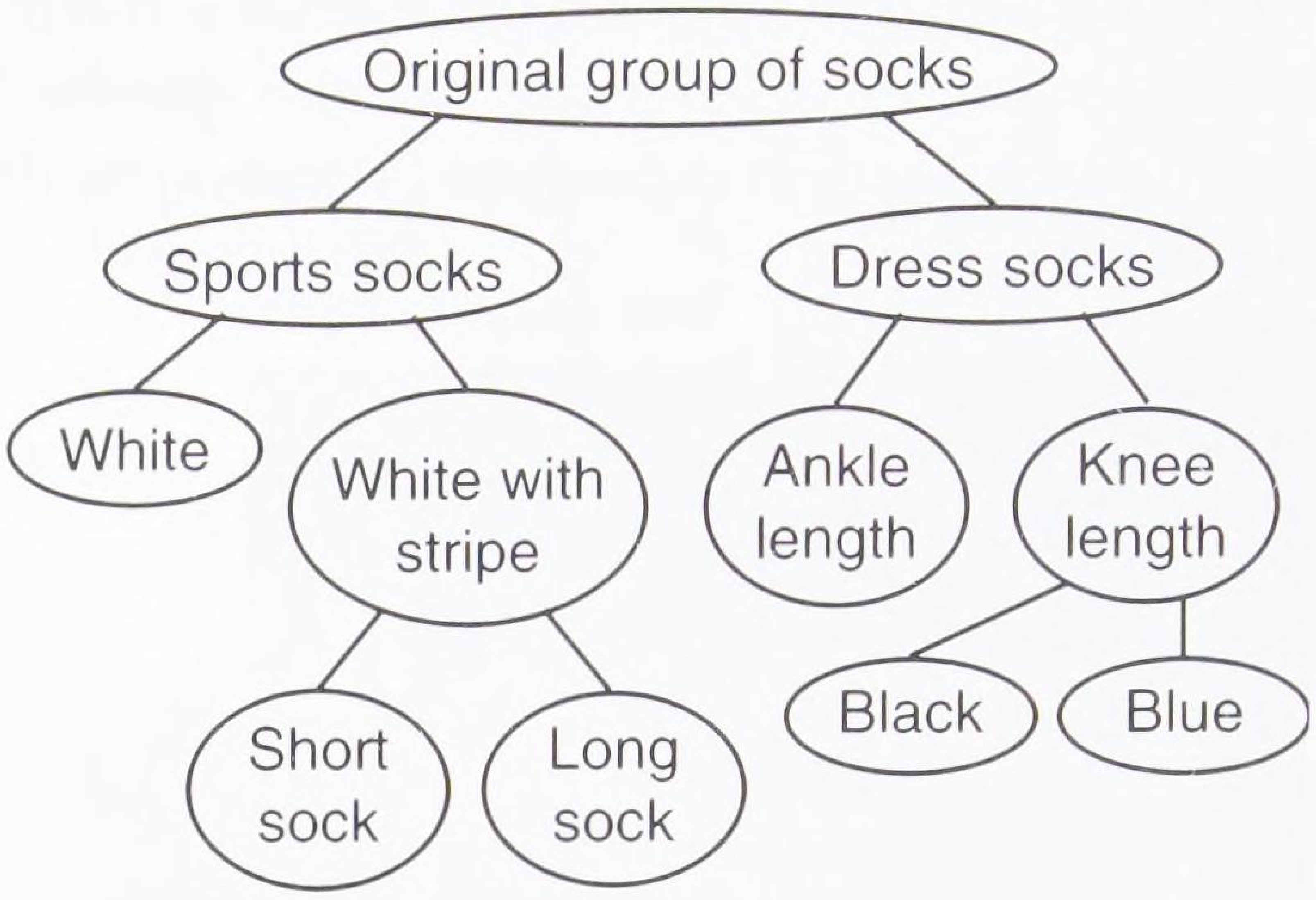
You may not realize it, but you impose order on the world around you. If your shirts hang in the closet together, your socks take up a corner of a dresser drawer, or your favorite audio cassettes are stacked together, you have used the skill of classifying.

Classifying is grouping objects or events into groups based on common features. When classifying, you first make careful observations of the group of items to be classified. Select one feature that is shared by some items in the group but not others. Place the items that share the same feature in a subgroup. Place other items in subgroups based on other shared features. After you decide on the first feature that divides the items into subgroups, examine the items for other features and further divide each subgroup into smaller and smaller groups until the items have no features in common.

How would you classify these socks?



Classify the socks based on observable features. You might classify sport socks in one subgroup and dress socks in another. The sport socks could be subdivided into a white subgroup and a striped subgroup. Note that for each feature selected, each sock only fits into one subgroup. Keep selecting features until all the socks are classified. The chart shows one classification.



Remember, when you classify, you are grouping objects or events for a purpose.

Sequencing

A sequence is an arrangement of things or events in a particular order. A common sequence with which you are familiar is students sitting in alphabetical order. Think also about baking chocolate chip cookies. Certain steps have to be followed in order for the cookies to taste good.

When you are asked to sequence things or events, you must first identify what comes first. You then decide what should come second. Continue to choose things or events until they are all in order. Then, go back over the sequence to make sure each thing or event logically leads to the next.

Suppose you wanted to watch a rented movie that just came out on videotape. What sequence of events would you have to follow to watch the movie? You would first turn the television set to Channel 3 or 4. You would then turn the videotape player on and insert the tape. Once the tape has started playing, you would adjust the sound and picture. Then, when the movie is over, you would rewind the tape and return it to the store.

Outlining

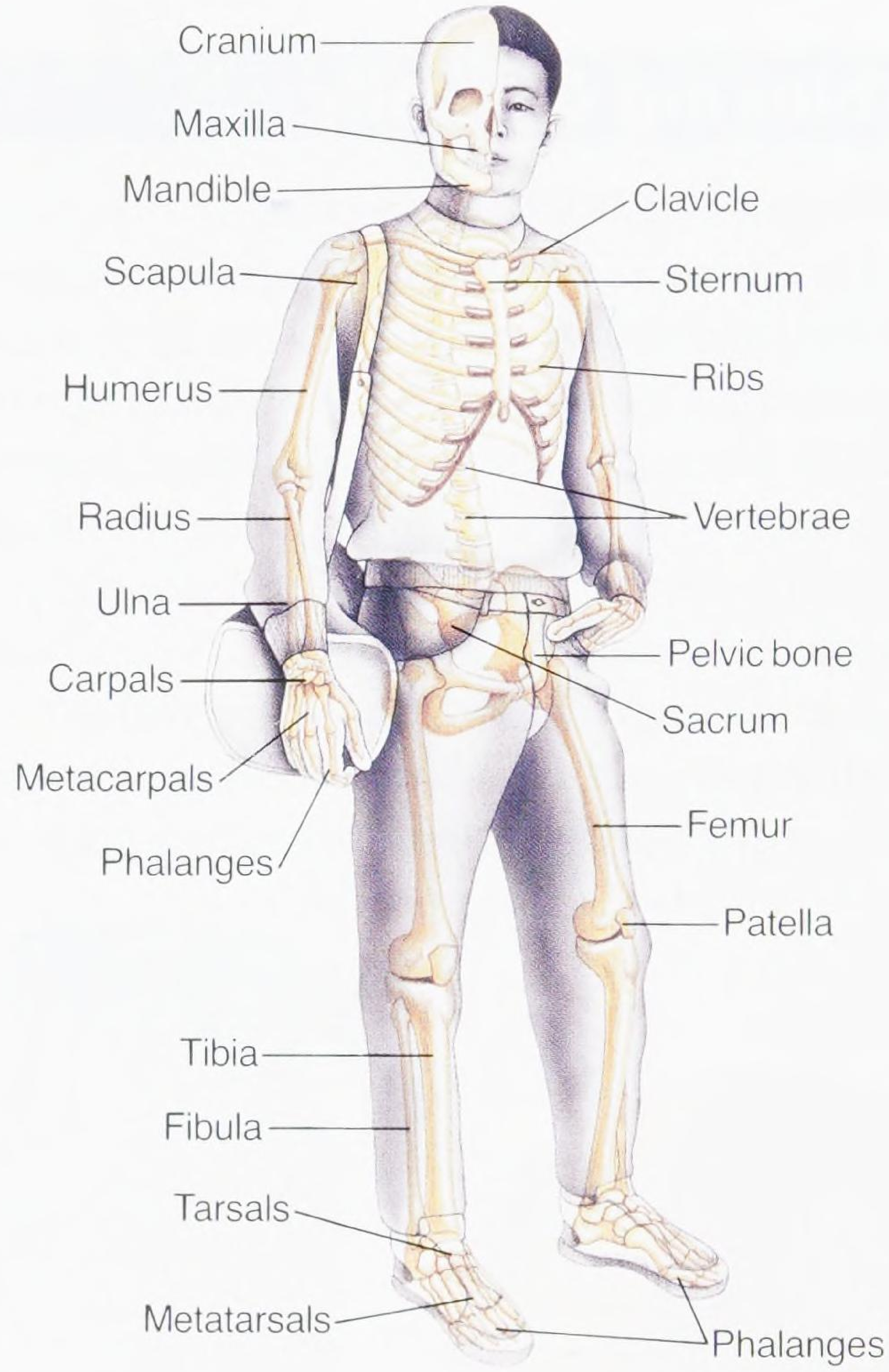
Have you ever wondered why teachers ask students to outline what they read? The purpose of outlining is to show the relationships between main ideas and information about the main ideas. Outlining can help you organize, remember, and review written material.

When you are asked to outline, you must first find a group of words that summarizes the main idea. This group of words corresponds to the Roman numerals in an outline. Next, determine what is said about the main idea. Ideas of equal importance are grouped together and are given capital letters. Ideas of equal importance are further broken down and given numbers and letters.

To get an idea how to outline, compare the following outline with your textbook.

Chapter 17 Bones and Muscles

I. The Skeletal System
    A. The Human Skeleton
        1. What Is a Skeleton?
            a. made up of bones
            b. a frame work
        2. Four Main Jobs
            a. shapes and supports the body
            b. protects internal organs
                1. skull protects brain
                2. backbone protects spinal cord


Cranium
Maxilla
Mandible
Scapula
Humerus
Radius
Ulna
Carpals
Metacarpals
Phalanges
Tibia
Fibula
Tarsals
Metatarsals
Clavicle
Sternum
Ribs
Vertebrae
Pelvic bone
Sacrum
Femur
Patella
Phalanges

Notice that the outline shows the pattern of organization of the written material. The bold face title is the main idea and corresponds with I. The letter A and numbers and letters that follow divide the rest of the text into supporting ideas.

Thinking Critically

Observing and Inferring

Imagine that you have just finished a volleyball game with your friends. You hurry home to get a cold drink. Opening the refrigerator, you see a jug of orange juice at the back of the top shelf. The jug feels cold as you grasp it. "Ah, just what I need," you think. You hear the tone rise as you pour the juice into a tall glass. When you quickly down the drink, you smell the oranges and enjoy the tart taste in your mouth.

As you imagined yourself in the story, you used your senses to make observations. The basis of all scientific investigation is observation. Scientists are careful to make their observations accurate. Instruments, such as microscopes or telescopes, are used to extend their senses.

Instruments are used to make measurements. When observations involve measurements, they are called quantitative observations. Because measurements are easy to communicate and provide a concrete means of comparing collected data, scientists use them whenever possible.

When you make observations in science, you may find it helpful first to examine the entire object or situation. Then, look carefully for details using your sense of sight. Write down everything you see before using another sense to make additional observations. Continue until you have used all five senses.

Scientists often use their observations to make inferences. An inference is an attempt to explain or interpret observations or to determine what caused the events you observed. For example, if you observed a CLOSED sign in a store window around noon, you might infer the owner is taking a lunch break. But, perhaps the owner has a doctor's appointment or has taken the day off to go fishing. The only way to be sure your inference is correct is to investigate further.

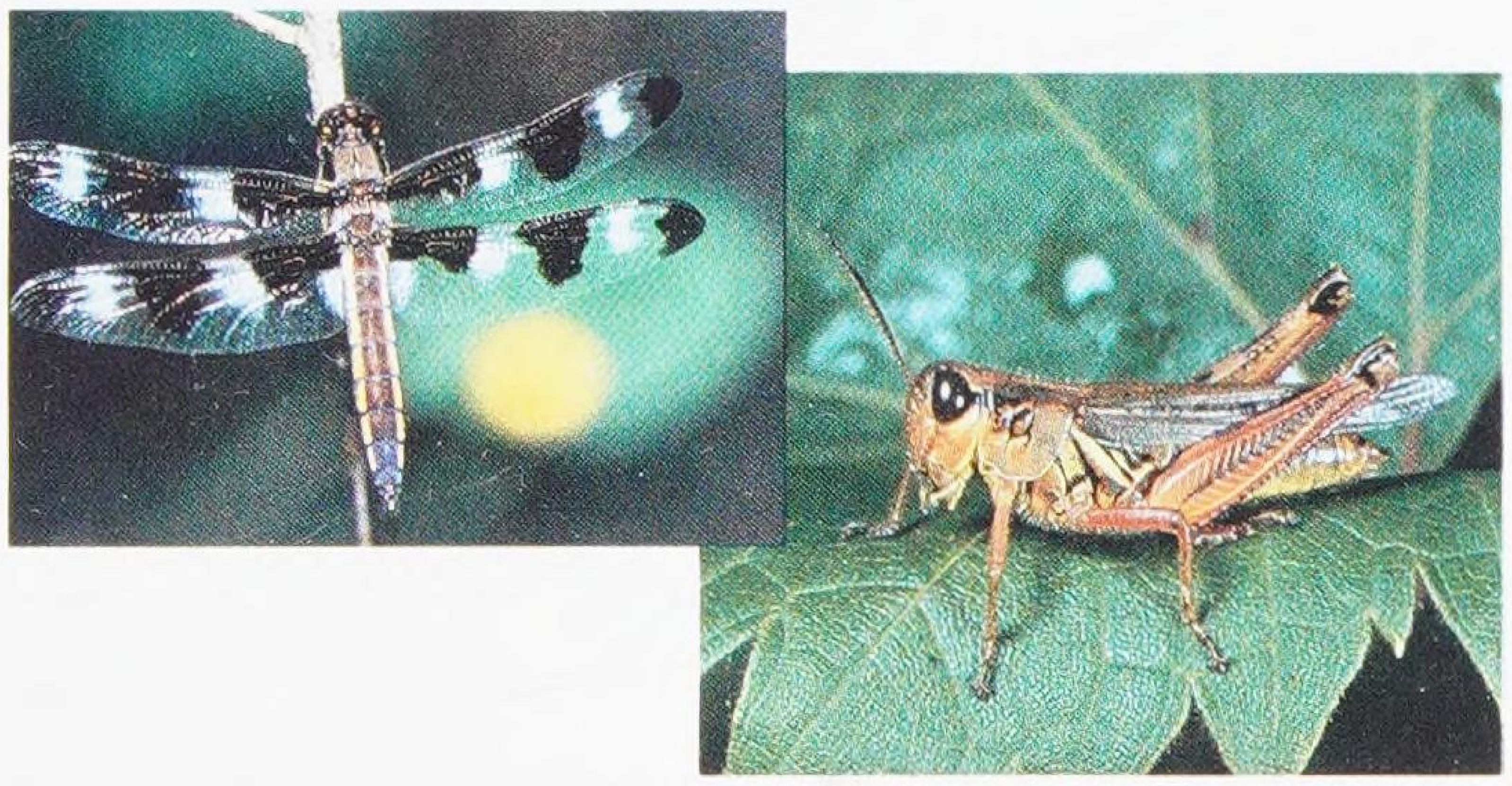
When making an inference, be certain to make accurate observations and to record them carefully. Then, based on everything you know, try to explain or interpret what you observed. If possible, investigate further to determine if your inference is correct.

Sorry WE'RE CLOSED
BUSINESS HOURS
MON. TO
TUES. TO
WED. TO
THUR. TO
FRI. TO
SAT. TO
SUN. TO

Comparing and Contrasting

Observations can be analyzed and then organized by noting the similarities and differences between two or more objects or situations. When you examine objects or situations to determine similarities, you are comparing. Contrasting is looking at similar objects or situations for differences.

Suppose you were asked to compare and contrast a grasshopper and a dragonfly. You would start by examining your observations. You then divide a piece of paper into two columns. List ways the insects are similar in one column and ways they are different in the other. After completing your lists, you report your findings in a table or in a graph.



Similarities you might point out are that both have three body parts, two pairs of wings, and chewing mouthparts. Differences include grasshoppers cause damage to crops but dragonflies destroy harmful insects or the grasshopper flies short distances but the dragonfly can fly long distances.

Recognizing Cause and Effect

Have you ever observed something happen and then tried to figure out why or how it came about? If so, you have observed an event and inferred a reason for the event. The event or result of action is an effect, and the reason for the event is the cause.

Suppose that every time your teacher fed fish in a classroom aquarium, she tapped the food container on the edge. Then, one day she tapped the edge of the aquarium to make a point about an ecology lesson. You observe the fish swim to the surface of the aquarium to feed.

What is the effect and what would you infer would be the cause? The effect is the fish swimming to the surface of the aquarium. You might infer the cause to be the teacher tapping on the edge of the aquarium. In determining cause and effect, you have made a logical inference based on careful observations.

Perhaps, the fish swam to the surface because they reacted to the teacher's waving hand or for some other reason. When scientists are unsure of the cause for a certain event, they often design controlled experiments to determine what caused their observations. Although you have made a sound judgment, you would have to perform an experiment to be certain that it was the tapping that caused the effect you observed.

Designing an Experiment

Designing an experiment allows you to develop your scientific skills through investigations. Such skills include measuring in SI, hypothesizing, using variables, constants and controls, and interpreting data.

Measuring in SI

You are probably familiar with the metric system of measurement. The metric system is a uniform system of measurement developed by scientists in 1795. The development of the metric system helped scientists avoid problems with different units of measurement by providing an international standard. A modern form of the metric system called the International System, or SI, was adopted for worldwide use in 1960.

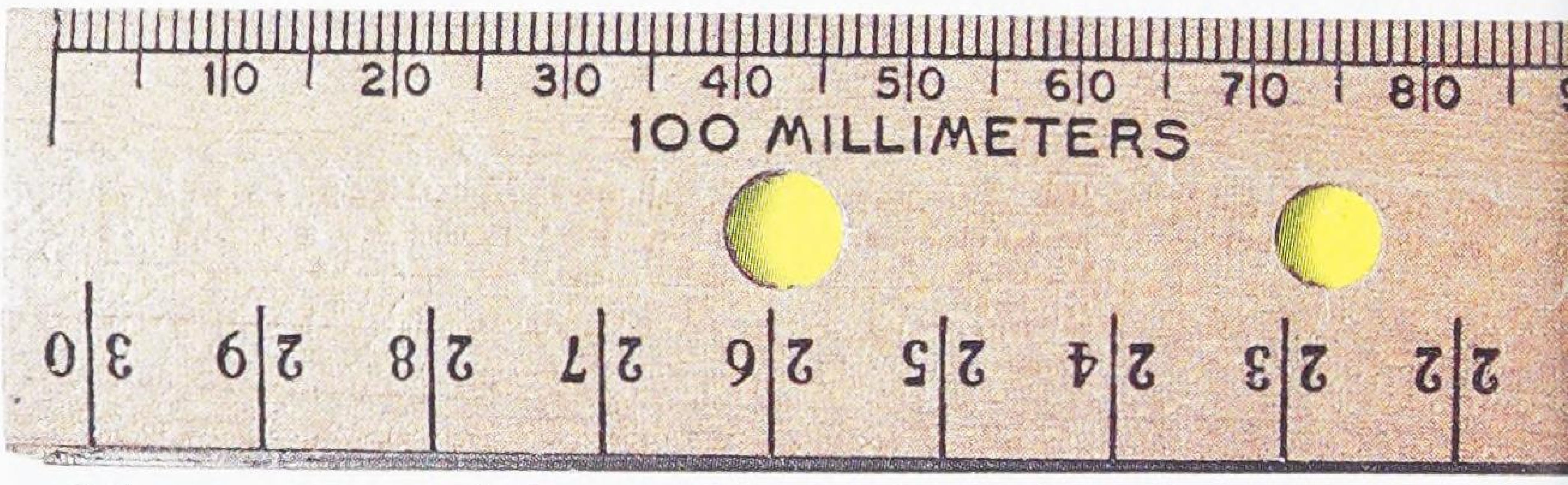
The metric system is easy to use because it names units systematically and has a decimal base. For example, meter is the base unit for measuring length, gram for measuring mass, and liter for measuring volume. Unit sizes vary by multiples of ten. When changing from smaller units to larger, you divide by ten. When changing from larger units to smaller, multiply by ten. Prefixes are used to name larger and smaller units. The following table lists common metric prefixes and their meanings.

METRIC PREFIXES

Prefix	Symbol		Meaning
kilo-	k	1 000	thousand
hecto-	h	100	hundred
deka	da	10	ten
deci-	d	0.1	tenth
centi	c	0.01	hundredth
milli-	m	0.001	thousandth

Do you see how the prefix *kilo-* attached to the unit *gram* is *kilogram* or 1 000 grams, or the prefix *deci-* attached to the unit *meter* is *decimeter* or one tenth (0.1) of a meter?

The meter is the SI unit used to measure distance. To visualize the length of a meter, think of a baseball bat. A baseball bat is about one meter long. When measuring smaller distances, the meter is divided into smaller units called centimeters and millimeters. A centimeter is one hundredth (0.01) of a meter which is about the size of the width of the fingernail on your little finger. A millimeter is one thousandth of a meter (0.001), about the thickness of a dime.



Most metersticks and metric rulers have lines indicating centimeters and millimeters. Look at the illustration. The centimeter lines are the longer numbered lines and the shorter lines between the centimeter lines are millimeter lines.

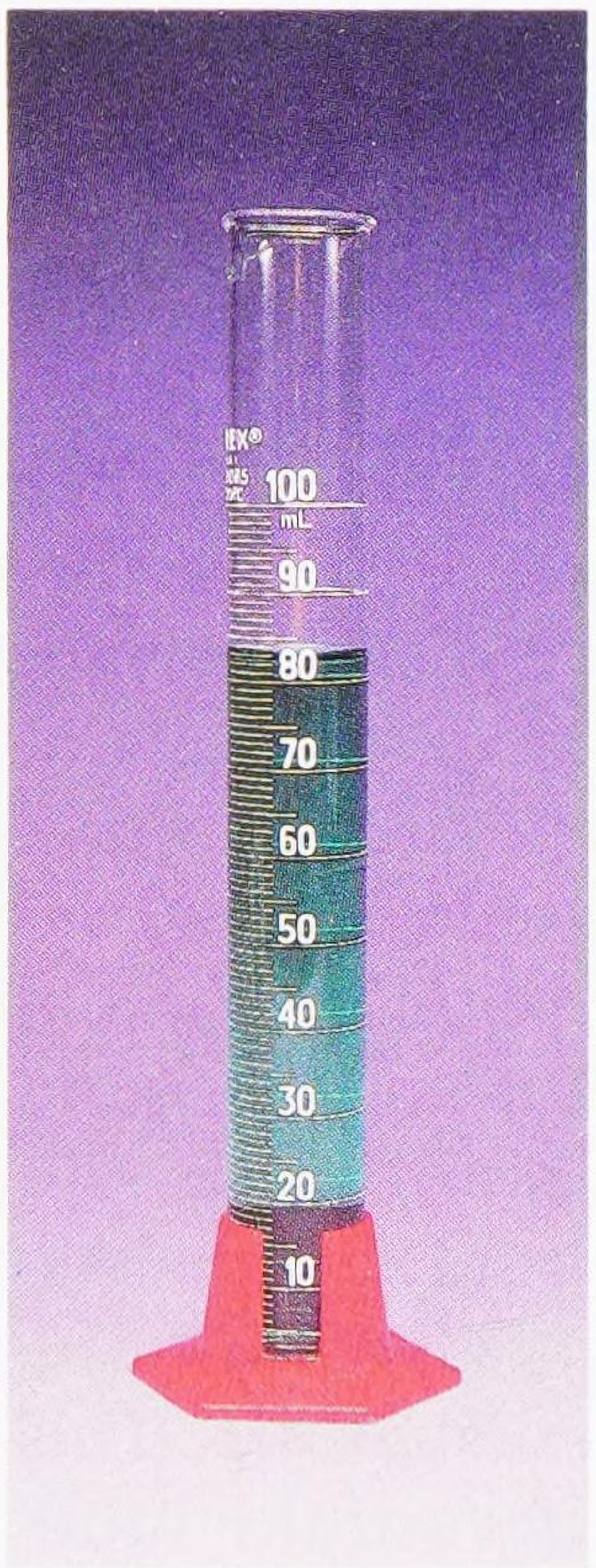
When using a metric ruler, you must first decide on a unit of measurement. You then line up the 0 centimeter mark with the end of the object being measured, and read the number of the unit where the object ends.

Units of length are also used to measure the surface area. The standard unit of area is the square meter (m^2), or a square one meter long on each side. Similarly, a square centimeter (cm^2) is a square one centimeter long on each side. Surface area is determined by multiplying the number of units in length times the number of units in width.

The volume of rectangular solids is also calculated using units of length. The cubic meter (m^3) is the standard SI unit of volume. A cubic meter is a cube one meter on a side. You can determine the volume of rectangular solids by multiplying length times width times height.

Liquid volume is measured using a unit called a liter. You are probably familiar with a two-liter soft drink bottle. One liter is about one-half of the two-liter bottle. A liter has the volume of 1000 cubic centimeters. Since the prefix *milli-* means thousandth (0.001), a milliliter equals one cubic centimeter. One milliliter of liquid would fill a cube measuring one centimeter on each side.

During science activities you will measure liquids using beakers and graduated cylinders marked in milliliters. A graduated cylinder is a tall cylindrical container marked with lines from bottom to top. Each graduation usually represents one milliliter.

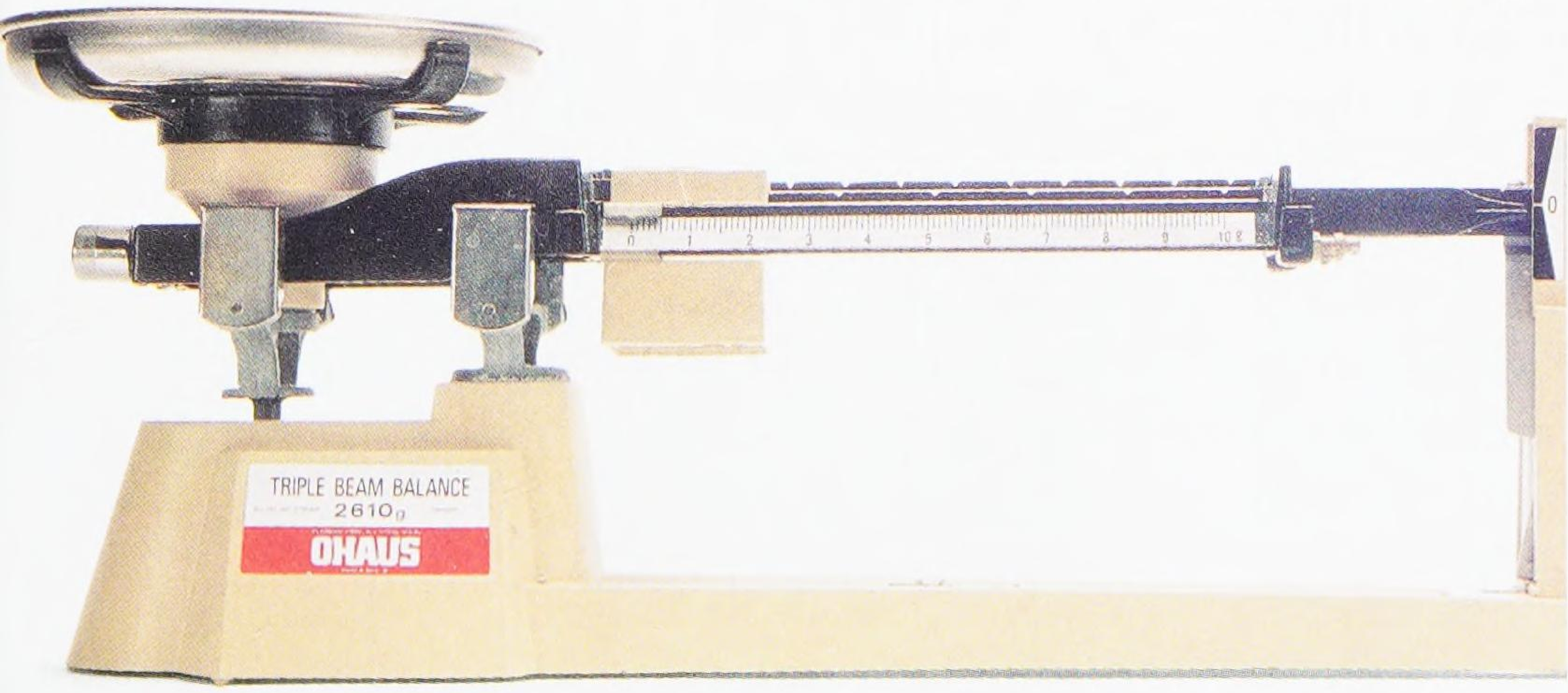


Scientists use a balance to find the mass of an object in grams. You will likely use a beam balance similar to the one illustrated. Notice that on one side of the beam balance is a pan and on the other side is a set of beams. Each beam has an object of a known mass called a rider that slides on the beam.

You must be careful when using a balance. When carrying the balance, hold the beam support with one hand and place the other hand under the balance. Also, be careful what you place on the pan. Never place a hot object or pour chemicals directly on the pan. Determine the mass of a suitable container and place dry or liquid chemicals into the container. Then determine the mass of the container and the chemicals. Finally, calculate the mass of the chemicals by subtracting the mass of the empty container.

Before you find the mass of an object, you must set the balance to zero by sliding all the riders back to the zero point. Check the pointer to make sure it swings an equal distance above and below the zero point on the scale. If the swing is unequal, find and turn the adjusting screw until you have an equal swing.

You are now ready to use the balance to find the mass of the object. Place the object on the pan. Slide the rider with the largest mass along the beams until the pointer drops below the zero point. Then move it back one notch. Repeat the process on each beam until the pointer swings an equal distance above and below the zero point. Read the masses indicated on the beams. The sum of the masses is the mass of the object.



Hypothesizing

What would you do if the combination lock on your locker didn't work? Would you try the combination again? Would you check to make sure you had the right locker? You would probably try several possible solutions until you managed to open the locker.

Scientists generally use experiments to solve problems and answer questions. An experiment is a method of solving a problem in which scientists use an organized process to attempt to answer a question.

Experimentation involves defining a problem and formulating and testing hypotheses, or proposed solutions, to the problem. Each proposed solution is tested during an experiment which includes making careful observations and collecting data. After analysis of the collected data, a conclusion is formed and compared to the hypothesis.

Imagine it's after school, and you are changing clothes. You notice a brownish-black spot on a favorite shirt. Your problem is how to remove the stain from the shirt without damaging the shirt. You think that soap and water will remove the stain. You have made a hypothesis, or proposed a solution to the problem. But, making a hypothesis is not enough. A hypothesis has to be something you can test. You try soap and water, but the stain doesn't budge.

Then you decide that you need to use a stronger solvent than water. You have revised your hypothesis based on your observations. The new hypothesis is still only a proposed solution until you test it and examine the results. If the test removes the stain, the hypothesis is accepted. But, if the test doesn't remove the stain, you will have to revise and refine your hypothesis again.

Using Variables, Constants, and Controls

When scientists perform experiments, they are careful to manipulate or change only one condition and keep all other conditions in the experiment the same. The condition that is manipulated is called the independent variable. The conditions that are kept the same during an experiment are called constants. The dependent variable is any change that results from manipulating the independent variable.

Scientists can only know that the independent variable caused the change in the dependent variable if they keep all other factors the same in an experiment. Scientists also use controls to be certain that the observed changes were a result of manipulation of the independent variable. A control is a sample that is treated exactly like the experimental group except that the independent variable is not applied to the control. After the experiment, the change in the dependent variable of the control sample is compared with any change in the experimental group. This allows you to see the effect of the independent variable.

Suppose you watch your guppies one morning and they don't seem as active as usual. You check the aquarium and notice that the aquarium heater is not working. You wonder how water temperature affects the activity level of guppies and decide to design an experiment. What would be your independent and dependent variables, constants, and control in your experiment? What would your hypothesis be?

This is how you might set up your experiment. Obtain several identical clear glass containers, and fill them with the same amount of water. Let the containers set.

On the day of your experiment, fill a container with an amount of aquarium water equal to that in the test containers. After measuring and recording the water temperature, heat and cool the other containers adjusting the water temperatures in the test containers so that two have higher temperatures and two have lower temperatures than the aquarium water temperature.

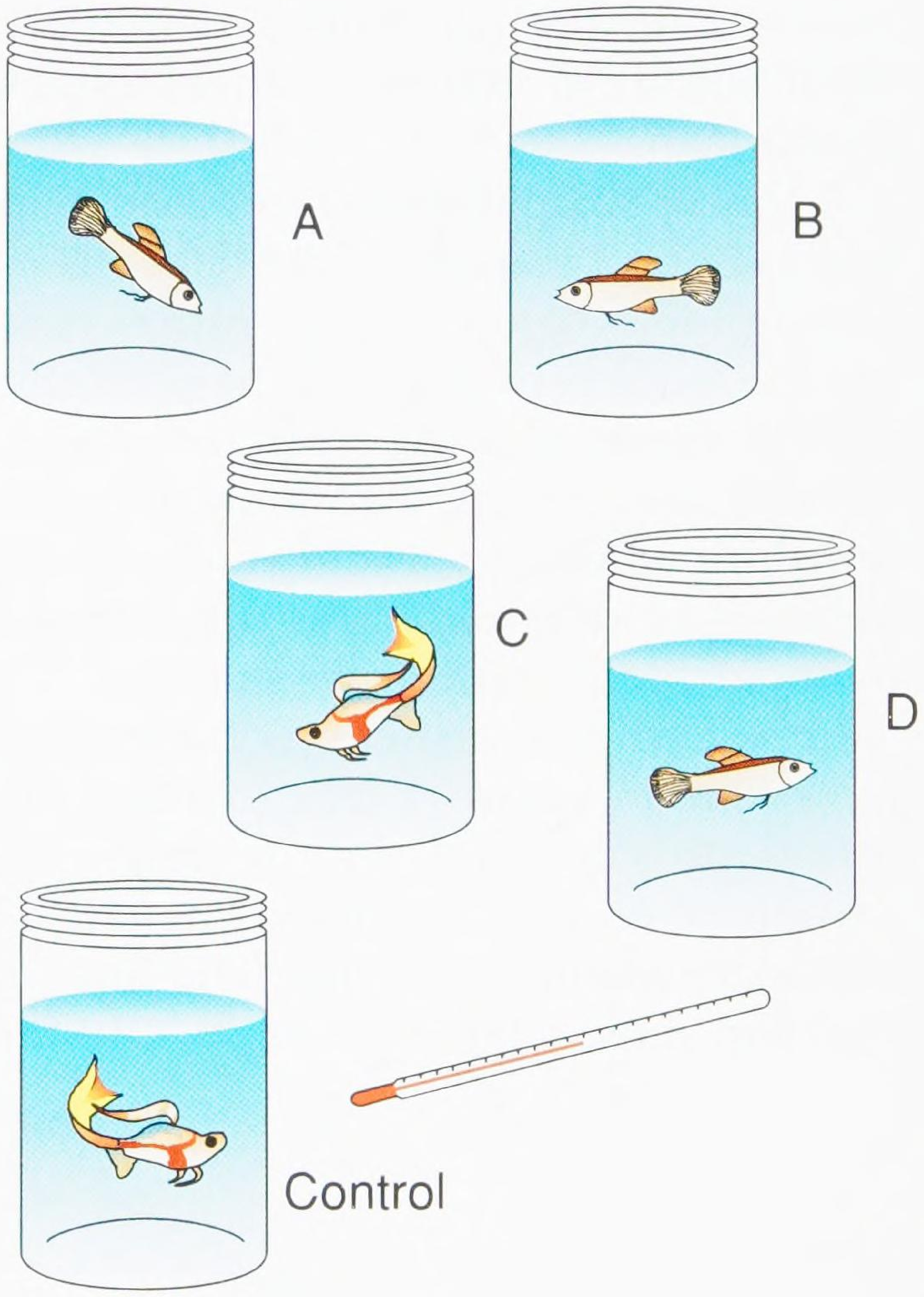
Place a guppy in each container. Count the number of horizontal and vertical movements each guppy makes during five minutes and record the data in a table. The data table might look like this:

Number of Guppy Movements

Container	Temperature (°C)	Number of movements
Aquarium Water	38	56
A	40	61
B	42	70
C	36	46
D	34	42

What are the independent and dependent variables in the experiment? Because you are changing the temperatures of the water, the independent variable is the water temperature. Since the dependent variable is any change that results from the independent variable, the dependent variable is the number of movements the guppy makes during five minutes.

What factors are constants in the experiment? The constants are using the same size and shape containers, filling them with equal amounts of water, and counting the number of movements during the same amount of time. What was the purpose of counting the number of movements of a guppy in an identical container filled with aquarium water? The container of aquarium water is the control. The number of movements of the guppy in the aquarium water will be used to compare the movements of the guppies in water of different temperatures.



Interpreting Data

After doing a controlled experiment, you must analyze and interpret the collected data, form a conclusion, and compare the conclusion to your hypothesis. Analyze and interpret the data in the table. What conclusion did you form? The data indicate that the higher the temperature the greater the number of movements of the guppy. How does the conclusion compare with your hypothesis? Was it supported by the experiment or not?

Graphic Organizers

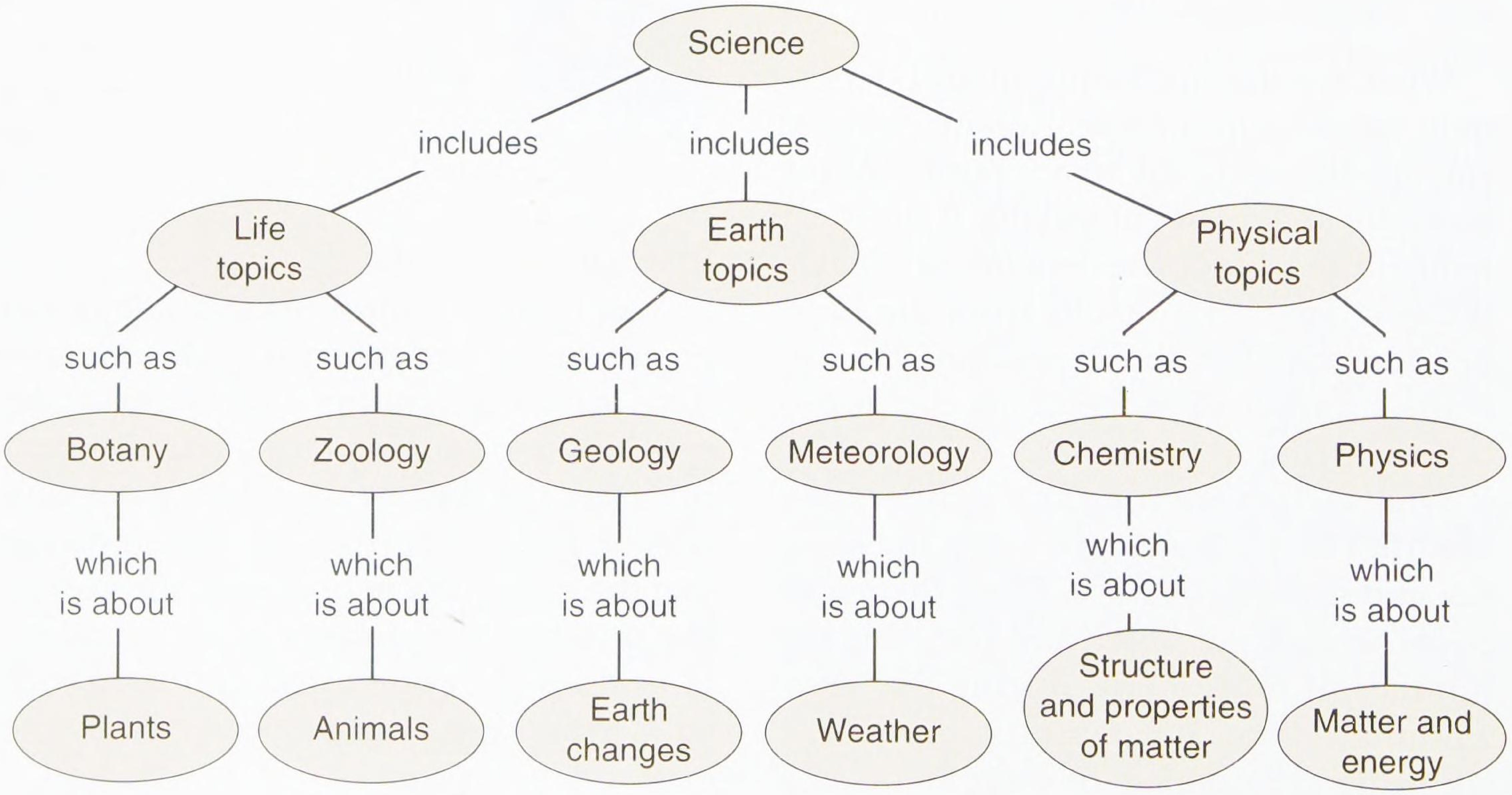
Concept Mapping

If you were taking an automobile trip, you would probably take along a road map. The road map shows your location, your destination, and other places along the way. By examining the map, you can understand where you are in relation to other locations on the map.

A concept map is similar to a road map. But, a concept map shows the relationship among ideas (or concepts) rather than places. A concept map is a diagram that visually shows how concepts are related. Because the concept map shows the relationships among ideas, it can clarify the meaning of ideas and terms and help you to understand what you are studying.

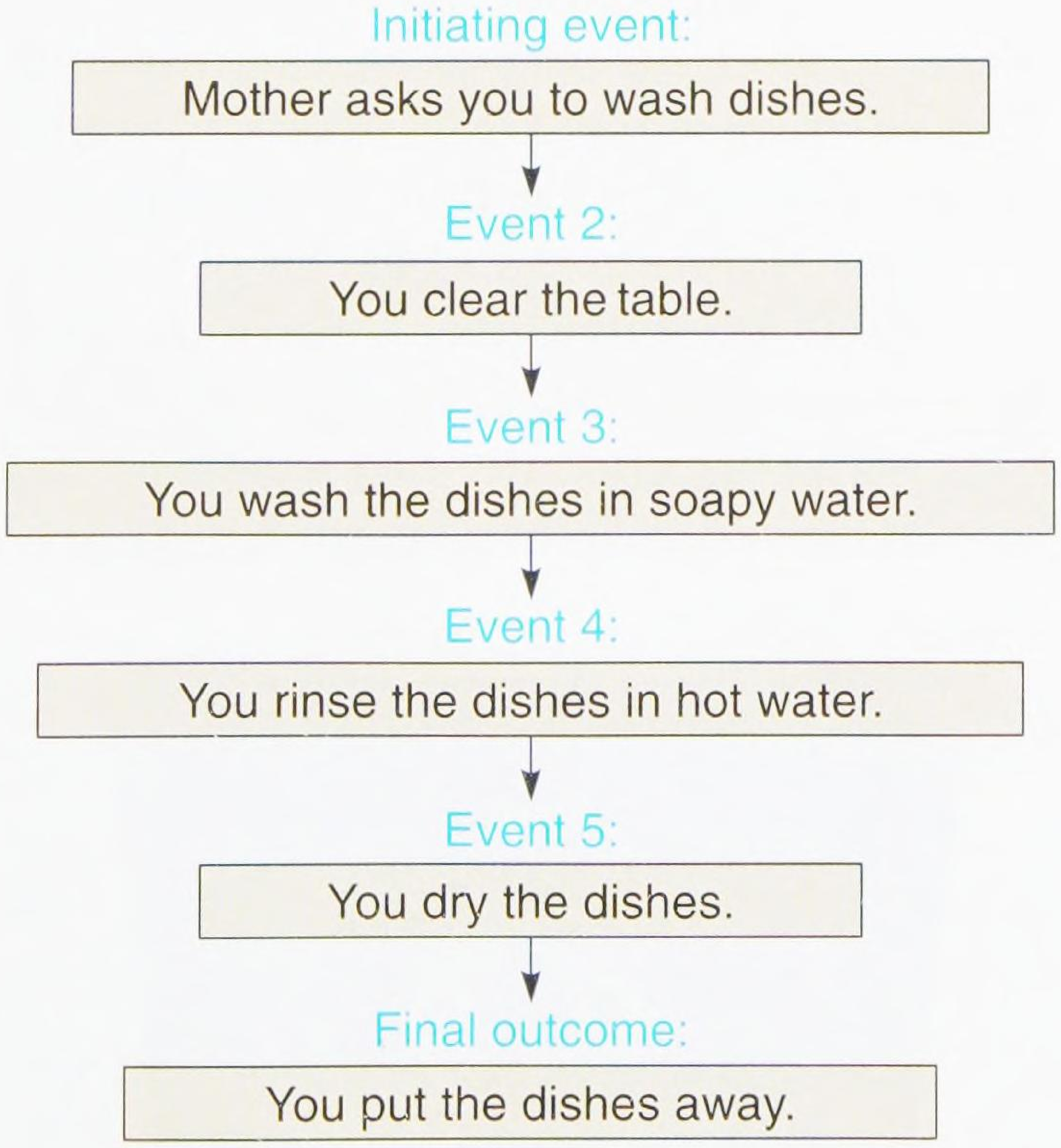
Look at the construction of a concept map called a **network tree.** Notice how some words are circled while others are written on connecting lines. The circled words are science concepts. The lines in the map show related concepts, and the words written on them describe relationships between the concepts. A network tree can also show more complex relationships between the concepts. For example, because chemical processes occur in plants and animals, a line labeled "affected by" could be drawn from plants and animals to chemistry. Another example of a relationship that crosses branches would be a line connecting Earth changes and matter and energy labeled "caused by interactions of." Earth changes are caused by interactions of matter and energy.

When you are asked to construct a network tree, state the topic and select the major concepts. Find related concepts and put them in order from general to specific. Branch the related concepts from the major concept and describe the relationships on the lines. Continue to write the more specific concepts. Write the relationships between the concepts on the lines until all concepts are mapped. Examine the concept map for relationships that cross branches, and add them to the concept map.


Science
includes
includes
includes
Life topics
Earth topics
Physical topics
such as
such as
such as
such as
such as
such as
Botany
Zoology
Geology
Meteorology
Chemistry
Physics
which is about
which is about
which is about
which is about
which is about
which is about
Plants
Animals
Earth changes
Weather
Structure and properties of matter
Matter and energy

An **events chain** is another type of concept map. An events chain map is used to describe ideas in order. In science, an events chain can be used to describe a sequence of events, the steps in a procedure, or the stages of a process.

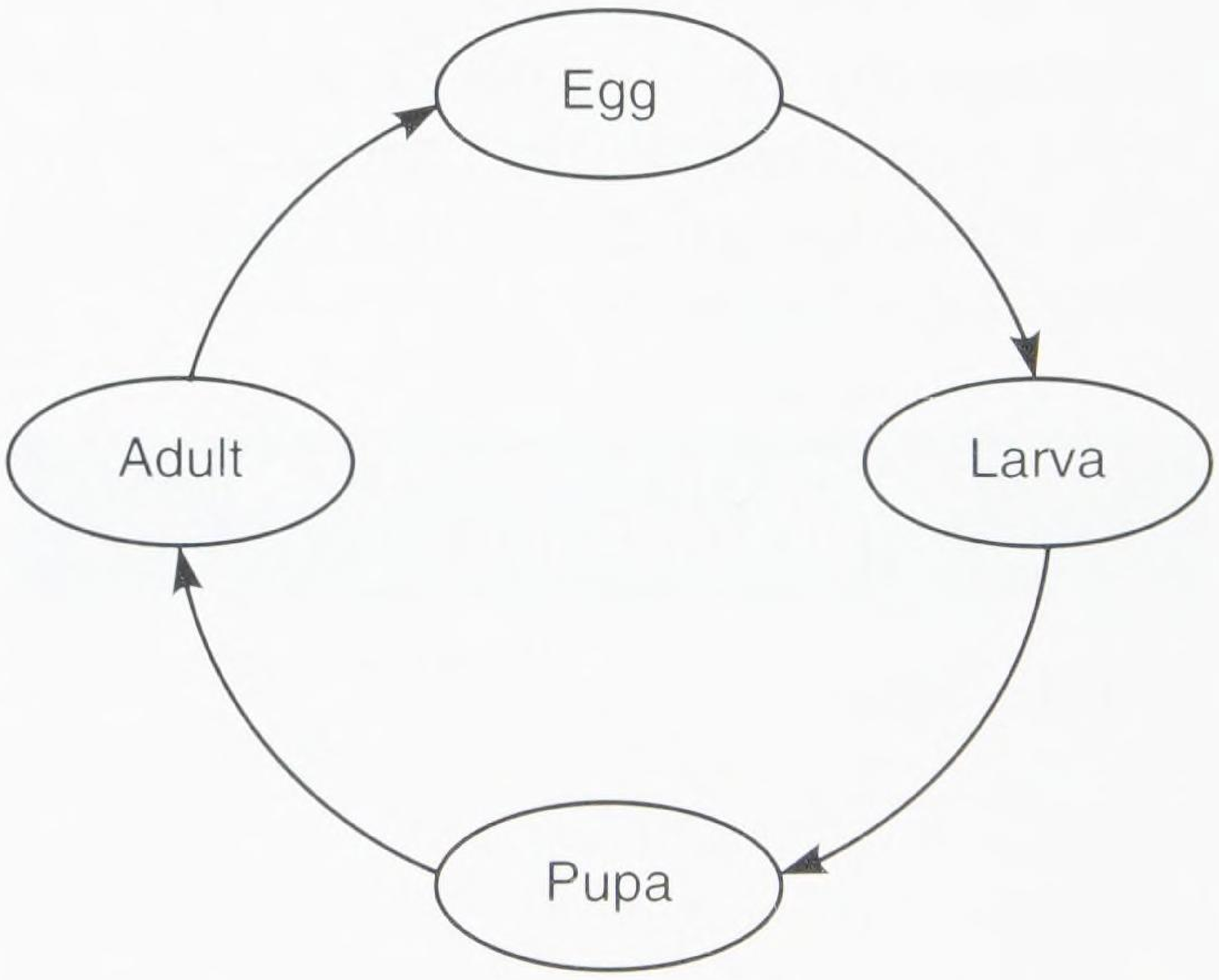
When making an events chain, you first must find the one event that starts the chain. This event is called the initiating event. You then find the next event in the chain and continue until you reach an outcome. Suppose your mother asked you to wash the dinner dishes. An events chain map might look like the one below. Notice that connecting words may not be necessary.


Initiating event:
Mother asks you to wash dishes.
Event 2:
You clear the table.
Event 3:
You wash the dishes in soapy water.
Event 4:
You rinse the dishes in hot water.
Event 5:
You dry the dishes.
Final outcome:
You put the dishes away.

A **cycle concept map** is a special type of events chain map. In a cycle concept map, the series of events do not produce an final outcome. The last event in the chain relates back to the initiating event.

As in the events chain map, you first decide on an initiating event and then list each important event in order. Since there is no outcome and the last event relates back to the initiating event, the cycle repeats itself. Look at the cycle map of physical changes of water:

Complete Insect Metamorphosis


Egg
Larva
Pupa
Adult

There is usually not one correct way to create a concept map. As you are constructing a map, you may discover other ways to construct the map that show the relationships between concepts better. If you do discover what you think is a better way to create a concept map, do not hesitate to change it.

Concept maps are useful in understanding the ideas you have read about. As you construct a map, you are constructing knowledge and learning. Once concept maps are constructed, you can use them to review and study and to test your knowledge.

Making and Using Tables

Browse through your textbook and you will notice many tables both in the text and in the activities. The tables in the text arrange information in such a way that it is easier for you to understand. Also, many activities in your text have tables to complete as you do the activity. Activity tables will help you organize the data you collect during the activity so that it can be interpreted easily.

Most tables have a title telling you what is being presented. The table itself is divided into columns and rows. The column titles list items to be compared. The rows headings list the specific characteristics being compared. Within the grid of the table the collected data is recorded. Look at the following table:

EFFECT OF EXERCISE ON HEARTBEAT RATE

Pulse taken	Heartbeat rate individual	class average
at rest	73	72
after exercise	110	112
1 minute rest after exercise	94	90
5 minute rest after exercise	76	75

What is the title of this table? The title is "Effect of Exercise on Heart Rate." What items are being compared? The heart rates for an individual and the class average are being compared at rest and for several durations after exercise.

What is the average heart rate of the class 1 minute after exercise? To find the answer you must locate the column labeled "class average" and the row "1-minute rest after exercise." The data contained in the box where the column and row intersect is the answer. Did you answer 90? Whose heart rate was 110 after exercise? If you answered the individual, you have an understanding of how to use a table.

RECYCLED MATERIALS

Day of Week	Paper (kg)	Aluminum (kg)	Plastic (kg)
Mon.	4	2	0.5
Wed.	3.5	1.5	0.5
Fri.	3	1	1.5

To make a table, you simply list the items compared in columns and the characteristics compared in rows. Make a table and record the data comparing the mass of recycled materials collected by a class. On Monday, students turned in 4 kg of paper, 2 kg of aluminum, and 0.5 kg of plastic. Wednesday, they turned in 3.5 kg of paper, 1.5 kg of aluminum, and 0.5 kg of plastic. On Friday, the totals were 3 kg of paper, 1 kg of aluminum, and 1.5 kg of plastic. If your table looks like the one shown, you should be able to make tables to organize data.

Making and Using Graphs

After scientists organize data in tables, they often display the data in graphs. A graph is a diagram that shows a comparison between variables. Since graphs show a picture of collected data, they make interpretation and analysis of the data easier. The three basic types of graphs used in science are the line graph, bar graph, and pie graph.

A line graph is used to show the relationship between two variables. The variables being compared go on two axes of the graph. The independent variable always goes on the horizontal axis, called the *x*-axis. The dependent variable always goes on the vertical axis or *y*-axis.

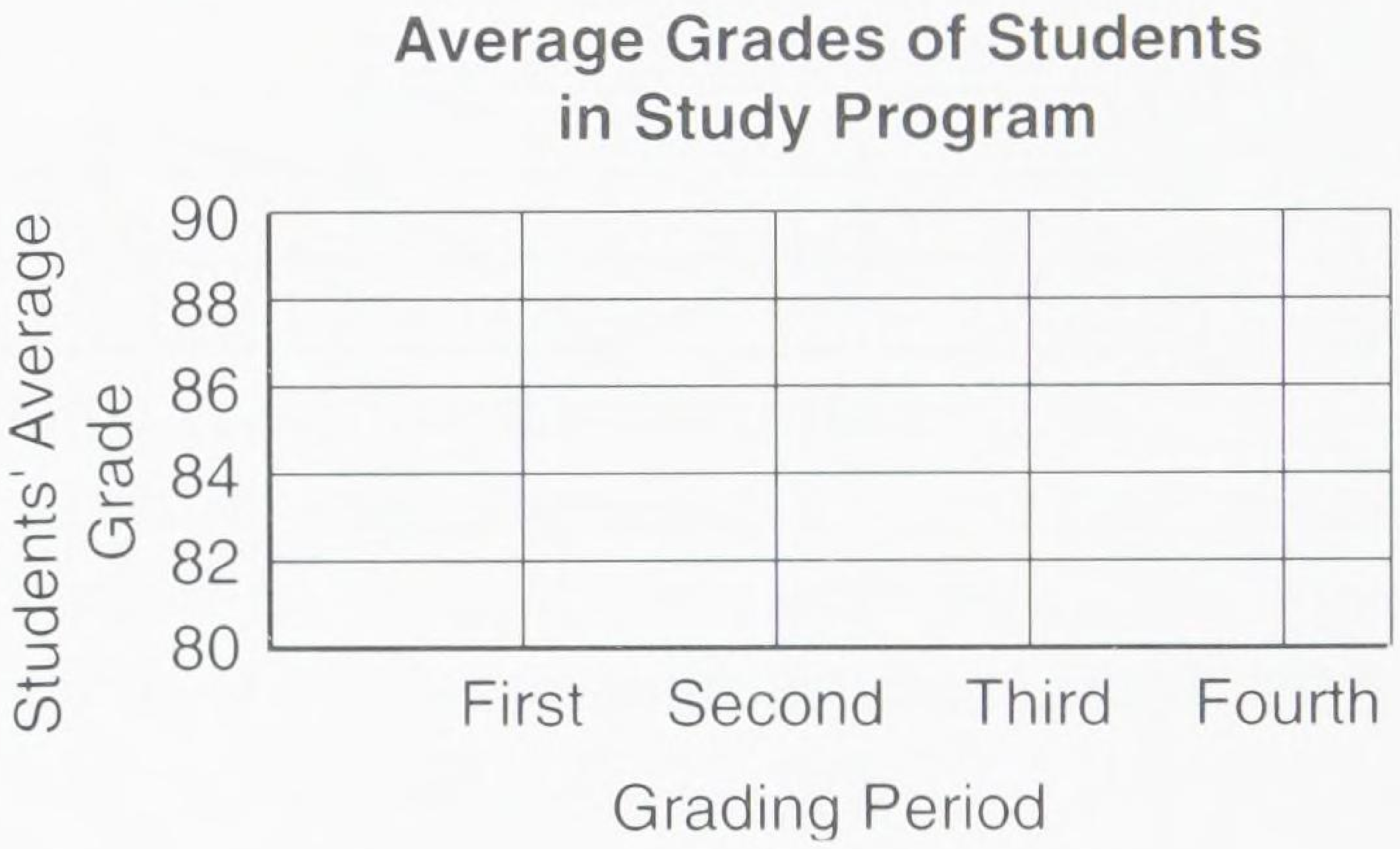
Suppose a school started a peer study program with a class of students to see how it affected their science grades.

AVERAGE GRADES OF STUDENTS IN STUDY PROGRAM

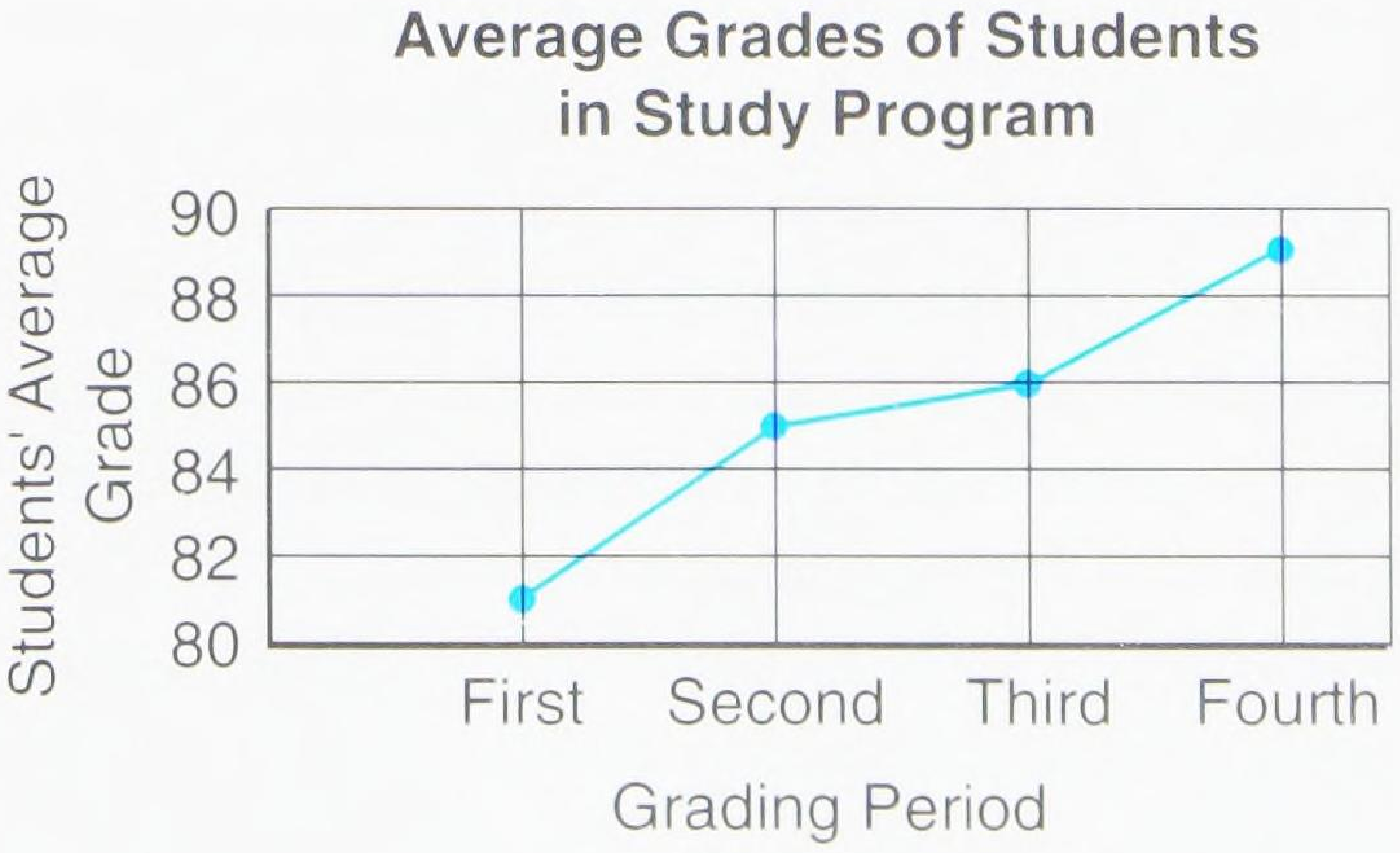
Grading Period	Average Science Grade
First	81
Second	85
Third	86
Fourth	89

You could make a graph of the grades of students in the program over a period of time. The grading period is the independent variable and should be placed on the *x*-axis of your graph. The average grade of the students in the program is the dependent variable and would go on the *y*-axis.

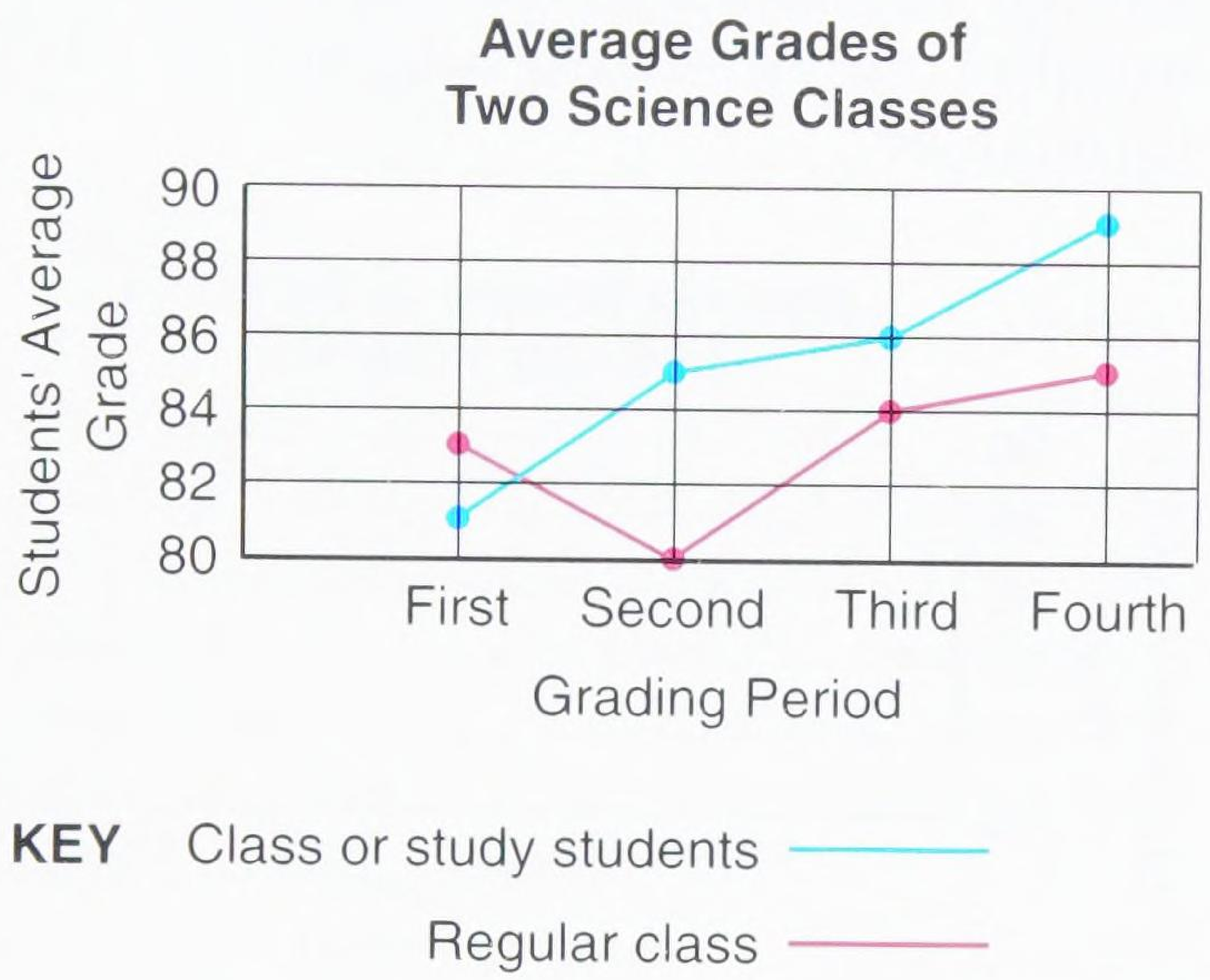
After drawing your axes, you would label each axis with a scale. The *x*-axis simply lists the grading periods. To make a scale of grades on the *y*-axis, you must look at the data values. Since the lowest grade was 81 and the highest was 89, you know that you will have to start numbering at least at 81 and go through 89. You decide to start numbering at 80 and number by twos through 90.



Next, plot the data points. The first pair of data you want to plot is the first grading period and 81. Locate "First" on the *x*-axis and 81 on the *y*-axis. Where an imaginary vertical line from the *x*-axis and an imaginary horizontal line from the *y*-axis would meet, place the first data point. Place the other data points the same way. After all the points are plotted, connect them with a smooth line.



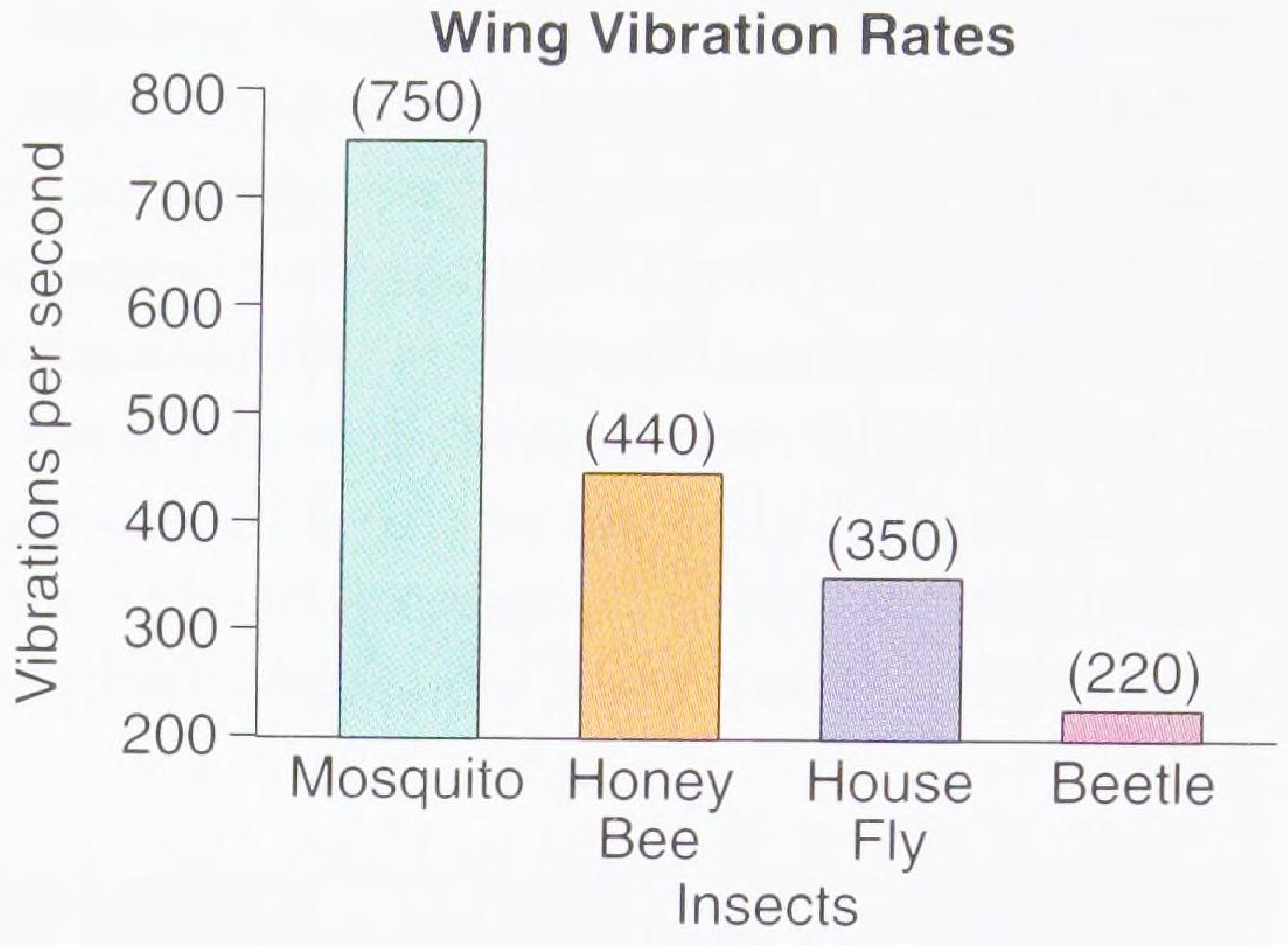
What if you wanted to compare the average grades of the class in the study group with the grades of another class? The data of the other class can be plotted on the same graph to make the comparison. You must include a key with two different lines each indicating a different set of data.



Bar graphs are similar to line graphs, except they are used to show comparisons between data or to display data that does not continuously change. In a bar graph, thick bars show the relationships between data rather than data points.

To make a bar graph, set up the *x*-axis and *y*-axis as you did for the line graph. The data is plotted by drawing thick bars from the *x*-axis up to an imaginary point where the *y*-axis would intersect the bar if it was extended.

Look at the bar graph comparing the wing vibration rates for different insects. The independent variable is the type of insect, and the dependent variable is the number of wing vibrations per second. The number of wing vibrations for different insects is being compared.



A pie graph uses a circle divided into sections to display data. Each section represents part of the whole. When all the sections are placed together, they equal 100 percent of the whole.

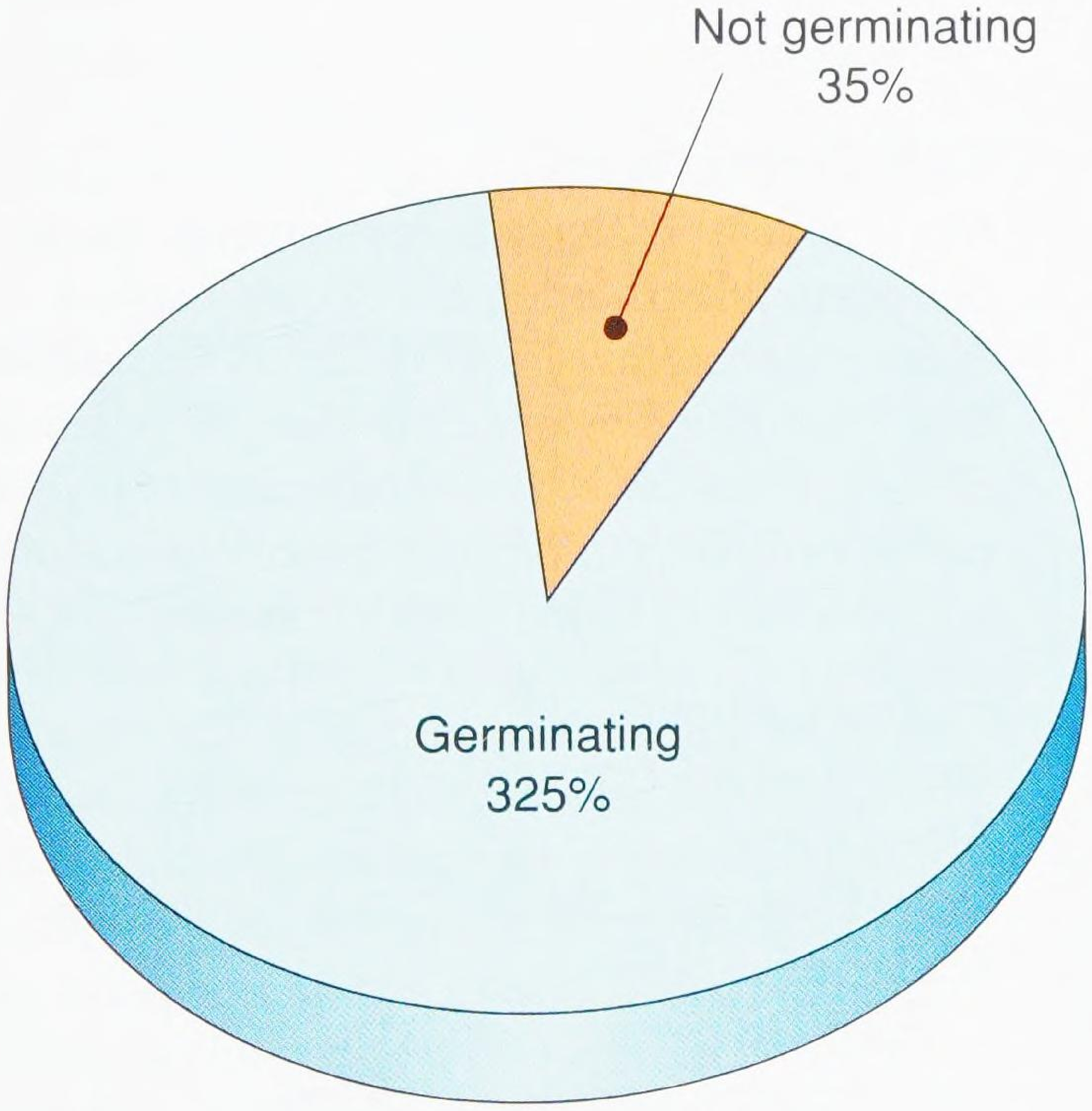
Suppose you wanted to make a pie graph to show the number of seeds that germinated in a package. You would have to determine the total number of seeds and the number of seeds that germinated out of the total. You count the seeds and find that there are 143 seeds in the package. Therefore, the whole pie will represent this amount.

You plant the seeds and determine that 129 seeds germinate. The group of seeds that germinated will make up one section of the pie graph, and the group of seeds that did not germinate will make up another section.

To find out how much of the pie each section should take, you must divide the number of seeds in each section by the total number of seeds. You then multiply your answer by 360, the number of degrees in a circle. Round your answer to the nearest whole number. The number of seeds that germinated would be determined as follows:

$$\frac{129}{143} \times 360 = 324.75 \text{ or } 325 \text{ degrees}$$

To plot this group on the pie graph, you need a compass and a protractor. Use the compass to draw a circle. Then, draw a straight line from the center to the edge of the circle. Place your protractor on this line and use it to mark a point on the edge of the circle at 325 degrees. Connect this point with a straight line to the center of the circle. This is the section for the group of seeds that germinated. The other section represents the group of seeds that did not germinate. Complete the graph by labeling the sections of your graph and giving the graph a title.



Interpreting Scientific Illustrations

Illustrations are included in your science textbook to help you understand, interpret, and remember what you read. Whenever you encounter an illustration, examine it carefully and read the caption. The caption is a brief comment that explains or identifies the illustrations.

Some illustrations are designed to show you how the internal parts of a structure are arranged. Look at the illustrations of the stem in Figure 11-3 on page 256. The stems have been cut so that they show sections that are at right angles to the length of each stem. This type of illustration is called a cross section. If the stems were cut lengthwise in half, the sections would be called longitudinal sections.

Symmetry refers to a similarity or likeness of parts. Many organisms and objects have symmetry. When something can be divided into two similar parts lengthwise, it has bilateral symmetry. Look at the illustrations in Figure 13-3 on page 304. The right side of the butterfly looks very similar to the left side. It has bilateral symmetry.

Other organisms and objects have radial symmetry. Radial symmetry is the arrangement of similar parts around a central point. The sand dollar in Figure 13-3 has radial symmetry. See how it can be divided anywhere through the center into similar parts.

Some organisms and objects can not be divided into two similar parts. If an organism or object can not be divided, it is asymmetrical. Think about an amoeba. Regardless of how you try to divide an amoeba, you can not divide it into two parts that look alike.

Now look at the section of the dicot stem on page 256 again. Can you see that it has radial symmetry in cross section? If you were to make a longitudinal section through the dicot stem, you would see that it would have bilateral symmetry as well.

In your reading and examination of the illustrations, you will sometimes see terms that refer to the orientation of an organism. The word dorsal refers to the upper side or back of an animal. Ventral refers to the lower side or belly of the animal. The illustration of the planarian in Figure 13-12 on page 315 has both dorsal and ventral sides.

PROJECT 1 IN SEARCH OF CELLS

Even though cells make up ourselves and every living thing around us, we have not always known that cells are there. Some organisms, like protozoa, consist of only one cell, while other organisms, like people, consist of trillions of cells. While some cells, such as egg yolks, are large enough to be seen directly, most cells can not be seen without using special equipment. Centuries ago, scientists speculated about the nature of life. They weren't sure what organisms were made up of. Scientists were like detectives, trying to reconstruct a crime based only on clues. As technologies such as the microscope developed, scientists finally were able to observe cells. Cell research has sometimes involved reconstructing the nature of cells from looking at the activities and materials cells produced, rather than looking at cells themselves. As technology has improved, researchers have been able to observe more and more details about cells. Technology has taken us from the limitations of the hand lens to being able to see atoms.

Cell Detectives

Many different scientists have contributed to our present knowledge of the cell. Explore these scientists' lives and research to see how they contributed to our current understanding of cells. A list of some cell researchers is given below. Working in groups, choose one individual or a pair of individuals to research.

Eduard Buchner
Jean-Baptiste Carnoy
Albert Claude
Jewel Plummer Cobb
Rosalind Franklin
Camillo Golgi
Ross Harrison and Alexis Carrel
Sir Hans Krebs
Rita Levi-Montalcini
Jacob Monod
Mikhail Sememovich Tswett
James Watson and Francis Crick
August Weismann
Rudolf Virchow

For each subject, research the following information:

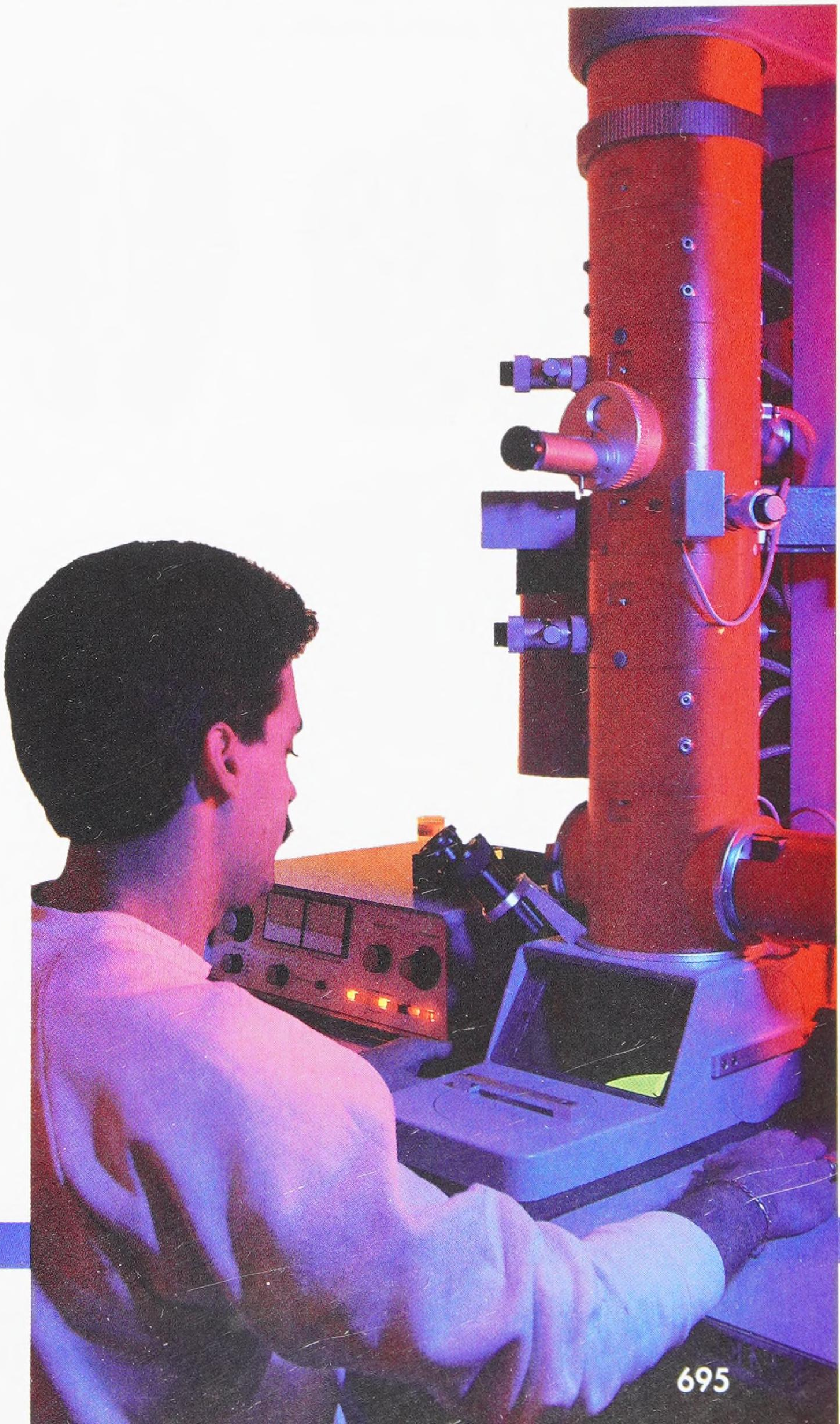
1. What was already known about the cell by the time your researcher was alive?
2. What kind of equipment did he or she have to work with?
3. What were the limitations of the equipment available?
4. What was taking place socially or politically at the time your researcher was living? How did he or she dress? How did scientists communicate with each other at that time?
5. What contribution did your researcher make to the knowledge of cells?
6. How did this person arrive at his or her contribution?

Using Your Research

After you have completed your research, write a scenario using the people in your group. This scenario should answer the research questions listed above. Design costumes that reflect the lifestyle of the scientists researched. The period of time, social class, and geographic location should all influence the costumes you design. Props should include models of the equipment available only at that particular time. Each group can present its scenario in chronological order. As a class, discuss how the scenarios show a history of cell research, and how they show a history of technological development as well.

Extension

Knowledge of the cell is far from complete. More and more as technology improves, new questions are asked. Today, a great deal of cell research centers on looking for solutions to various diseases that affect human life. What makes cells become cancerous? How can HIV be stopped? Will gene therapy be effective? Investigate the current research on muscular dystrophy, AIDS, cancer, or other diseases. How does this research make use of cell theory? What contributions might this research make to a better understanding of cells and how they work? Will you be the person in the next scenario?



PROJECT 2

KEEP THOSE TOES A-TAPPING!

Genetics influences the way you look, the way you act, and your health. Some genetically influenced characteristics are very noticeable. Skin color, hair color, eye color, and height are frequently used to describe people. Other genetically influenced characteristics are not thought about as much. Do you have attached or free earlobes? Can you taste PTC? Do you have a "hitchhiker's thumb?" Since it is hard to study a number of genetic traits all at once, this project focuses on gathering data on only one characteristic—the length of feet.

The length of the human foot is influenced by multiple genetic factors. To find out about this unique trait, first you will gather data. Then analyze it, and finally design a method to display results.

Collecting Data

Now comes the fun part. Work in a group. Each group will need to make a chart to record data. The chart will need to have horizontal heads that read Age, Sex, and Foot length (left/right) across the top. Down the side will be a number for each pair of feet you measure.

You can make a flexible ruler by placing a strip of paper over a plastic ruler with raised markings in centimeters. Rub over the ruler with your pencil and the markings will be transferred to your paper ruler.

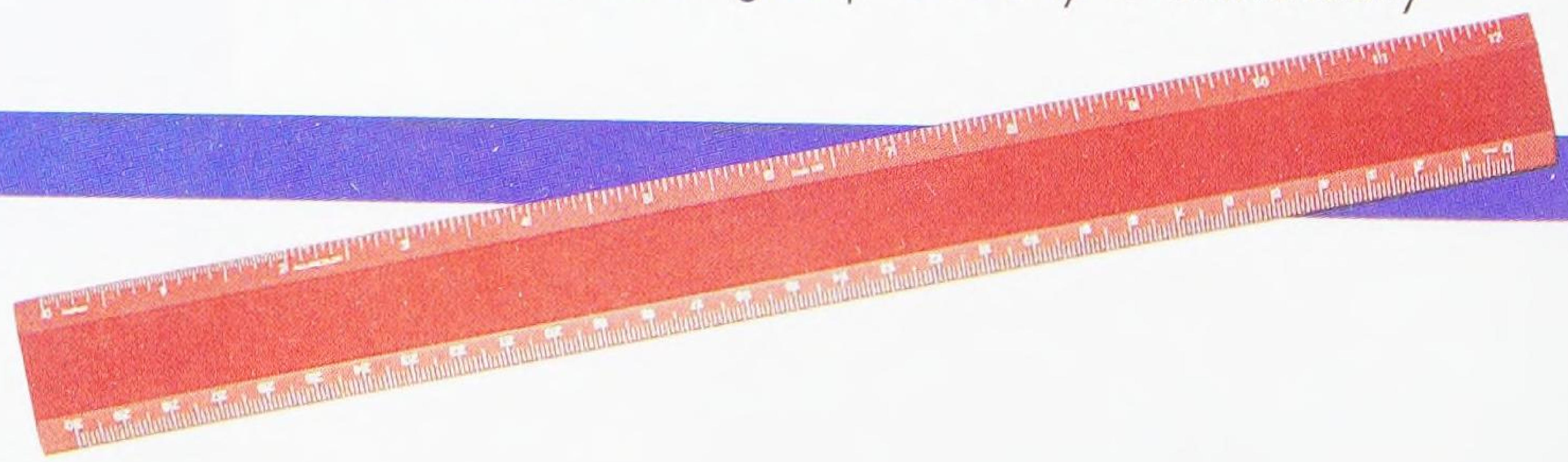
Each group should measure the feet of *at least* 10 people. These people should be a variety of ages. Include both males and females.

Compiling Data

As a class, decide how you are going to divide the age groups. Are you going to make three-year groupings (ages 0-2, 3-5, etc.) or five year groupings (0-4, 5-9, etc.)? Are you going to make smaller groupings for young children, but increase the age increments to 10 years for adults? Each group will now be assigned a particular age grouping and will make a chart (like the one used to record the data) for just that age group. Once these age group charts are ready, each group will fill in the data they collected on the appropriate age charts.

Data and Statistics

Once everyone has recorded the data they measured, each group is ready to statistically



analyze their particular age group chart. Calculate the mean, median, and mode of foot length for males and for females in a particular age group. The mean of male foot length is found by adding all the lengths of the male foot measurements in the age group and dividing by the number of male subjects in that age group. The same process is followed to find the mean of female foot length, but only the data on females is used. The foot lengths for all males within the age group should be listed in order from smallest to longest. The median of male foot length can then be found by finding the length in the exact middle of the list. (If there is an even number, the median is calculated by averaging the two middle lengths). The mode is the foot length that appears most frequently in the data. The same process is applied to the female foot length data to find female median foot length and the mode for female foot length.

Data Display

As a class, decide how to display the data you have analyzed so that the differences between males and females and among different age groupings can be easily seen. Make construction paper feet to display your statistics. Try to come up with a creative way of showing how foot length changes with age. You might also want to show the variation in foot size within age groupings.

Extension

Ask a local podiatrist for charts that list the average foot size for various age groups. See how close your results come to these published averages. Check with several local shoe stores to find out what sizes sell the most.

0.
INV
DEG
ON/AC
DRG
CE/C
√x
1/x
%
TAN
y^x
x²
SIN
COS
÷
INV
EE
LOG
LN
×
π
K
(
)
−
STO
7
8
9
+
RCL
4
5
6
=
SUM
1
2
3
EXC
0
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PROJECT 3

DON'T TOSS IT, COMPOST IT!

Have you ever thought about what happens to all the trash—paper cups, napkins, paper plates and plastic, spoons—after a football game or a dance? Of course, the first stop is a trash can or dumpster. This trash usually is picked up and trucked to a landfill. But our landfills are filling up, and we are running out of room for more. Some people are even suggesting that we send our garbage into space—littering on a cosmic scale!

The Compost Solution

Many communities try to cut down on landfill problems through recycling and composting. Your community may already recycle aluminum cans, glass, plastic, and paper products. Your family can also compost kitchen scraps and garden wastes. A compost heap allows organic garbage to break down and decay—a natural process that occurs when living things die. As these organic materials are broken down by bacteria, nutrients are released into the environment and can be used by other living organisms. When you compost, you are taking part in a process that has been going on for millions of years.

How It Works

Bacteria and fungi start the composting process by breaking down large organic materials. This releases heat as well as nutrients. The heat "cooks" and decomposes more material. A compost pile about 1 cubic meter in size works best to generate the heat required to make the process work. The pile needs to be turned or sifted regularly to keep material in contact with the warm center. The pile also needs to be kept moist and given plenty of air to keep the bacteria and fungi active.

Making a Compost Pile

Work in cooperative groups to learn about composting. One group could set up a standard control compost pile. A small, compost pile may be made in a large-mouthed glass jar or in a small, plastic aquarium. If outdoor composting is possible, you can make an enclosure using old window screens. Use four screens to make an open cube.

To build a control compost pile, alternate layers of soil (1 inch thick), a layer of kitchen or garden waste (2 inches thick), a sprinkle of fertilizer containing nitrogen, and a sprinkle of water. End with a top layer of soil. Although many types of wastes will decompose, do not add meat or fat—they can

attract animals. Any type of grass clippings, leaves, or fruit or vegetable peels work well. Ash from a fireplace and sawdust are good additions also. Make sure that the soil you use is not sterilized potting soil purchased from a store. After the pile is completed, use a shovel or garden fork to turn the compost once a week. This brings in oxygen and brings new material into the warm center. Your compost is ready when the materials have become uniformly brown and crumbly.

Each of the other student groups should design a compost pile that varies from the control pile in only one way. The amount of light, heat, or water the pile receives could be varied. The pile could be turned more or less frequently than the control pile. Each group should **hypothesize** how one change will affect the compost. "If we wet the pile well, then compost will be made more quickly." "If we don't turn the pile each week, it will make compost more quickly."

Analyzing the Differences

Each group will record the changes in their compost pile by finding its temperature and observing its smell, texture, and appearance. Make all observations of the compost pile before turning it with the fork or shovel. At the end of the experiment, groups should compare notes to decide which compost technique and recipe made good compost.

Extension

Find out how your community's trash and garbage is processed. Does the community compost grass clippings, or are clippings bagged to be picked up with the trash? Almost one quarter of the space in landfills in the United States is currently taken up by yard clippings! What advantages does composting have over landfills for organic materials? Perhaps some students would like to set up an on-going school composting program.

PROJECT 4

ANIMAL ENGINEERS

Have you ever found an abandoned animal home? You may not have thought of it that way, but a bird's nest, a hornet's nest, an anthill, or a rabbit burrow is a carefully engineered home. Just like your home, these homes provide shelter and protection from the environment and predators. A nest is usually made up of twigs. Nest sizes differ. A hummingbird nest is the size of a quarter. Bald eagle's nests are very large and may be 2 meters in diameter. Eagles mate for life, and a nesting pair may return to the same nest for as long as 30 years. Each year, they add a little more to their nest, and it grows.

Building an Animal Home

Animals use all types of materials in their homes. Animals build with twigs, mud, grass, hair, fur, stone, wood, or anything else they can find. Ospreys, large birds that live near the water, may use discarded fishing line to build nests, and frequently use seaweed. Some osprey nests have included bicycle tires and rubber gloves! Eagles in contrast, are very particular about what goes into their nests. Their nests are huge and made of sticks no less than one inch in diameter. Then they are lined with evergreens. These nests weight hundreds of pounds. They are built to last many years. Built in trees, an eagles nest is exposed to severe weather conditions.

Some animal homes are designed to blend into the environment. Prairie dog towns are basically underground. Other animals, like the magpie, a bird, like to collect shiny objects to "decorate" their homes.

Work in cooperative groups to pick an animal home to research. What materials does the animal use? How big is the home? What kind of environment is involved? What is the actual building process the animal uses? How long is the home expected to last? After researching a particular animal home, build a nest or burrow using the same materials and dimensions that the animal uses.

The Model Home Show

Plan a display of your model homes that shows what is special about this animal home. Show how it fits into the particular environment in which it is found. How does it offer protection and shelter for the animal involved? Does the environment influence the materials, and therefore, the structure of the animal house? Think about the wind and rain that some structures have to withstand.

Extension

Find out about animals that live in your area. What animals have you observed? If possible, go on a walk with a naturalist to learn more about the wildlife in your area. You may wish to focus particularly on bird nests. What types of materials do birds in your area use? Do they use twigs? Are the nests lined with feathers? Take pictures or make sketches of any nests you observe in your area. See if you can decide what kind of bird is using the nest just by its size and makeup.

PROJECT 5

WAS IT A REPTILE? WAS IT A BIRD?

Dinosaurs are popular attractions in stories, as action figures, on TV shows, and in museum displays. We have lots of pieces of evidence from dinosaur times, but this evidence can be woven into a variety of theories about the nature of dinosaurs, dinosaur lifestyles, and the cause of dinosaurs' demise. Originally, most scientists accepted the idea that dinosaurs were cold-blooded reptiles, slow-moving, and not terribly bright. Today, however, new evidence is causing scientists to question some of these ideas. What are some of the current controversies?

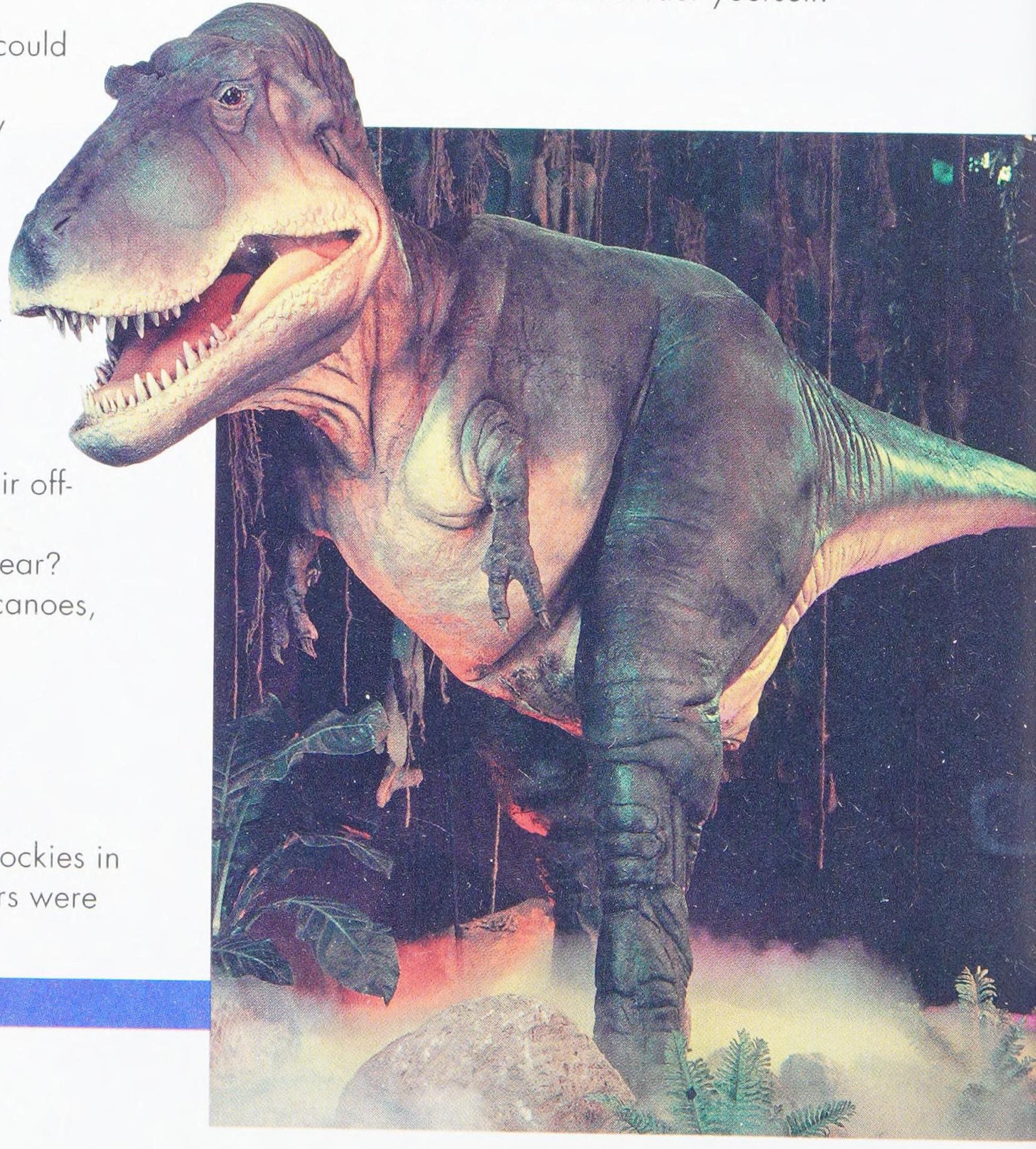
Theories in Conflict

Scientists have many questions about dinosaurs.

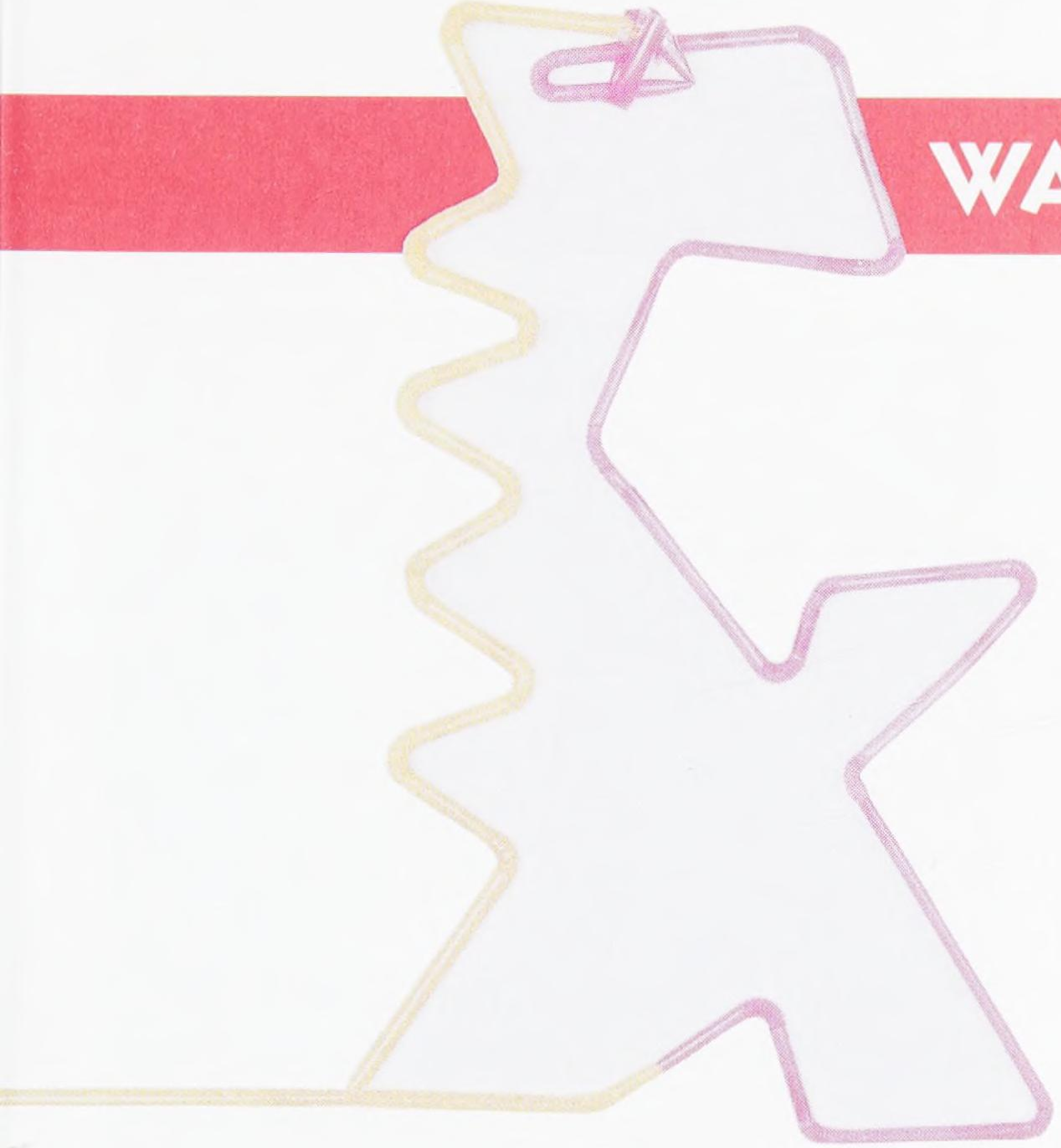
- Were dinosaurs cold-blooded or warm-blooded?
- Were the dinosaurs more closely related to reptiles or to birds?
- Were their bones solid like reptile bones or hollow inside like bird bones?
- Were dinosaurs slow-moving, or could some of them move quickly?
- Impressions of dinosaur skin show gland cells. Were these sweat glands or poison glands?
- Did dinosaurs live in hot, humid areas or hot, dry areas?
- Are bones that are found together from one dinosaur or from many? How can scientists tell?
- Are the eggs that are found with dinosaur bones their dinner or their offspring?
- What caused dinosaurs to disappear? Geological processes such as volcanoes, or comets from space?

Using a Theory to Design a Dinosaur

Jack Horner from the Museum of the Rockies in Bozman, Montana thinks that dinosaurs were more closely related to birds than to reptiles. He has found that many dinosaur bones appear to be hollow. By using the CAT scan X ray, he has determined that the skull and other bones contain many holes for blood vessels similar to those found in warm-blooded animals like birds. These ideas are still controversial, but you can use Dr. Horner's theory to construct a dinosaur yourself.

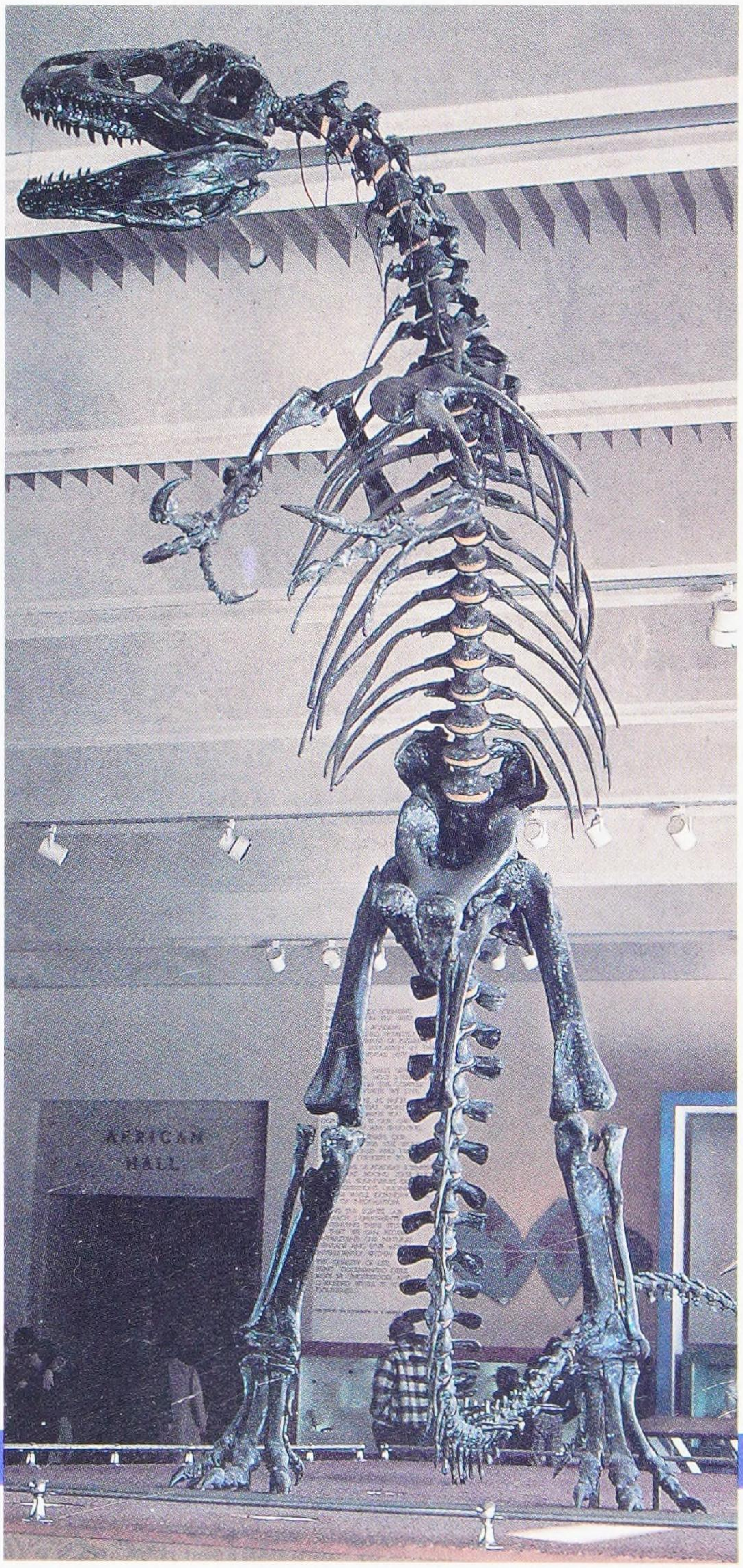


WAS IT REALLY WARM?



Extension

Discuss whether you agree with Dr. Horner's theory or not. What differences in dinosaur lifestyle are involved in accepting or rejecting Dr. Horner's theory? Do you have any different theory about the nature of dinosaurs? What evidence currently supports this theory? What further evidence would be needed to support your theory?



In a small group, look at books on dinosaurs and find one particular dinosaur that you can construct a model of. Make sure there is a diagram of the bone structure to give you guidance. Decide what materials you will use. Straws are hollow and lightweight like bird bones would be. Use bendable straws. The straws can be joined with tape.

Study the environments in which your dinosaur seems to have lived. Build your dinosaur and a realistic diorama showing its environment and something about its lifestyle.

Presenting Your Information

Prepare a brief description to explain the model and diorama. Arrange a day for groups to share these projects with each other. Look for connections between the various forms researched. Can a food web be constructed to connect the various dinosaurs?

PROJECT 6

ON YOUR MARK! GET SET! GO!

The Olympics is exciting sports competition, showing the human body performing at its peak. Many organ systems must work together in an athletic performance. The brain receives input from the sensory organs and directs and coordinates the action. Nerves carry the brain's directions, and stimulate the muscles to contract and to move the muscular and skeletal systems. In addition, nerves stimulate the circulatory and respiratory systems to speed the flow of blood with its increased supply of oxygen to the active muscles. The endocrine system also regulates performance through the hormones it releases. Adrenalin, for example, is released during times of stress, and may give people greater strength, speed, and quickness than usual—certainly useful to athletes in a tough competition!

Classroom Olympics

How fast can you run the 100-meter dash? Does training affect an athlete's ability to perform? For this project, you will plan, train, and participate in your own Olympic events. Working in groups, students will decide on physical activities that they would like to include in the classroom games. Each group is responsible for planning one event and demonstrating the event for the class. After the events are decided, each group will decide who will run the group's event and who will participate in the events planned by other groups.

Training

Like Olympic athletes, the classroom athletes will need to train. Unlike Olympic athletes, you are competing against your own record. First you want to look at your current performance level in your event. Have a partner record your level of achievement in the event so that you can compare your later performances to this baseline. Now you are ready to train. Have your partner measure your body functions, such as pulse rate and breaths per minute, before you begin. Record these measurements—they will show the normal speed of your circulatory and respiratory systems. Sit quietly for 5 minutes and record the same measurements. These will show your resting rates. Now train in your event for 5 minutes and record these measurements again. Have your circulatory and respiratory systems slowed down or speeded up?

When you train, be consistent in the way you measure performance. For example, if you are

doing a running event, time your runs on the same course each time. If you are jumping rope, you might measure how long you can jump rope without tripping up. When your training time is finished, switch jobs and let your partner train while you record. Although you will have some time to train in school, you may want to keep practicing at home—or at least do some conditioning. Athletes do conditioning exercises such as running to increase their strength and endurance in general, rather than practice a particular skill.

Graphing Your Results

Within your group, analyze the data you have collected on performance. On the *x*-axis, record the number of each trial. On the *y*-axis, record your performance in seconds, minutes, meters, number of jumps, etc. Use another graph to chart the pattern of your pulse and breathing rates. Has your level of performance changed at all? Have your pulse and breathing rates changed at all as your training progressed? Think about the organ systems involved in your event and explain the changes or lack of change.

Extension

You may wish to investigate the effect of learning on performance. Groups can design games or tasks that require learning a strategy and see how practice affects performance. One example of this kind of task would involve numbering small pieces of paper and having students pick them up in order.

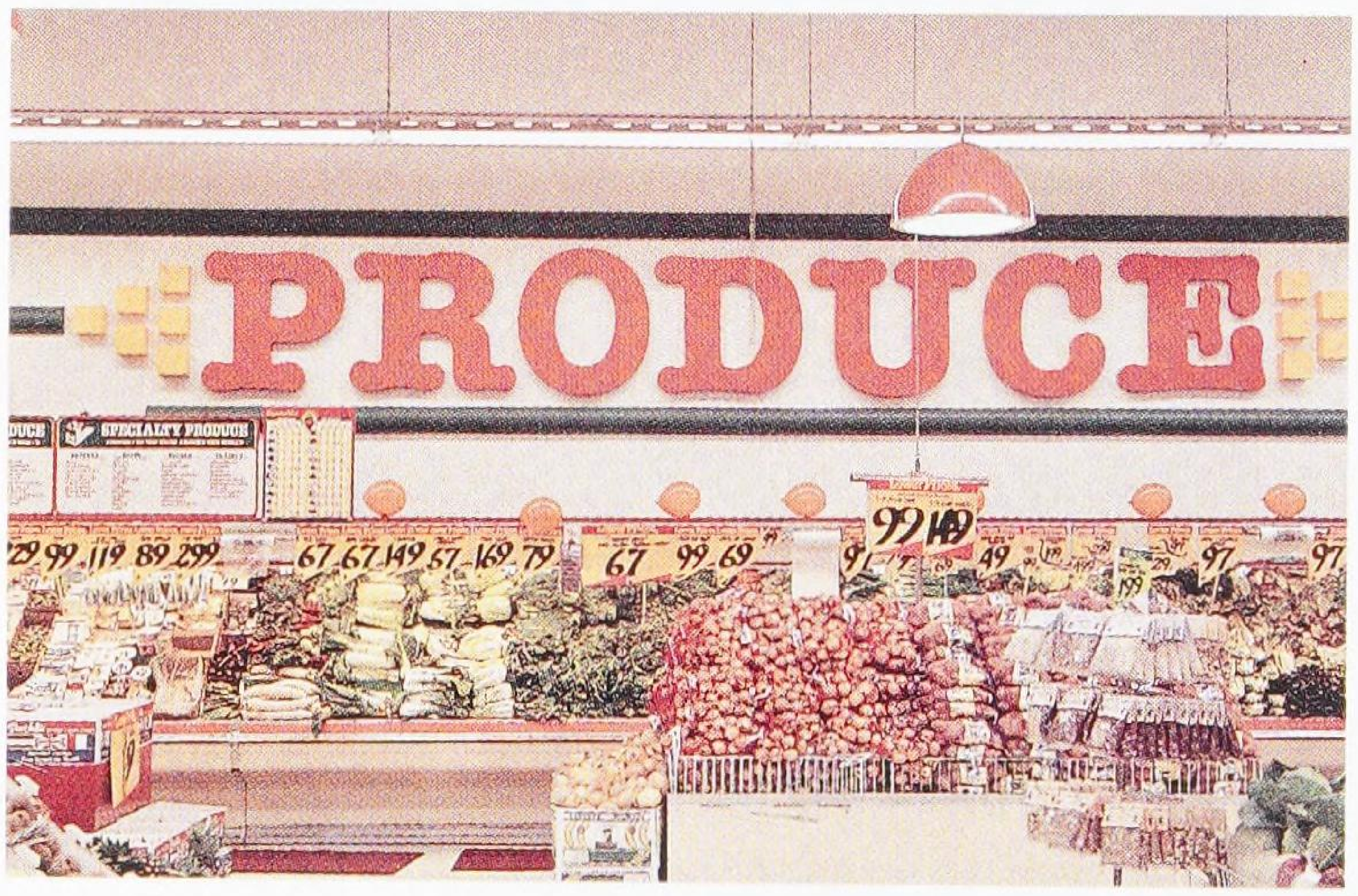
PROJECT 7

TO YOUR HEALTH!

What is a healthy lifestyle? Rest, exercise, and even your outlook on life—whether you are optimistic or pessimistic—all play a part. Having a good diet is important too, but not everyone agrees on what a healthy diet is. Different people also require different amounts of foods. Athletes frequently "eat to win," selecting meals that are high in carbohydrates. Males and females need different amounts of calcium. Body image affects diet greatly. Forty percent of 4th grade girls in the US are on some diet, frequently self-imposed, to either gain or lose weight. Some of these diets are based on healthy principles and make use of nutritious, low-fat foods. Others may be unhealthy, like those that rely almost exclusively on only one particular type of food.

Gathering Data

Work in groups of four or five. Each group should decide on a question to investigate people's attitudes about healthy eating habits, and devise a way to research these attitudes. Some examples of possible research approaches include:



1. Set up and administer a blind taste test to 50 people.
   Prepare the same recipe for banana bread or corn bread two ways. First, prepare the bread using a standard recipe. Then, make a "healthy" substitution of fruit for sugar, or canola oil for butter. Don't tell them the difference. See which recipe people prefer. Do different age groups have different preferences? Do they even notice a difference? Do males and females?

2. Research the focus of food advertising. Collect samples of advertising from various media sources and analyze the messages advertisers send to consumers about health and food. Do the messages appear to target any groups in particular? How can you tell?

3. Observe grocery store behavior.
   After obtaining permission from the store owner or manager, students can map the layout of food in a grocery store. The manager may be interviewed to discover why the store places items in particular places, and how "specials" are chosen and displayed. Students can also observe how people circulate through the store. Again, look for patterns by age group, sex, time of day, etc.

4. Design and give a questionnaire to 50 people.
   Decide on background information that might help you to categorize responses.
   For example:
   Male or female?
   Age?
   Occupation?
   Hobbies?
   Choose "yes" or "no" questions about what people actually eat and what they think they should eat.
   For example:
   Are you on a diet?
   Do you think you can get healthy food at a fast food restaurant?
   Do you exercise on a regular basis?

DAIRY
69
199
99
249
129

MEAT
129
789
299
249

Make sure the questions you choose are clear and will result in enough information for analysis. Ask for the information you want. Decide how many people you want to survey and make copies of the questionnaire. Decide when and where the survey will be done and who will conduct it. You may want to survey different groups (e.g., athletes, different age groups, etc.) to see if their answers vary.

5. Survey the food choices at your school. Analyze the daily menu for the cafeteria and the contents of any available snack machines. Do these foods encourage healthy eating? Students might also survey actual consumption patterns by randomly observing one table's occupants each day.

Presenting the Data

Each group must decide:

How will the data be summarized—a chart? A graph? A video-tape? A report?
How will you present your results? A poster? A verbal report? A written summary?

What Can You Do?

Discuss the results of the research as a class. Use what you have learned to make an ad campaign for healthy eating. This campaign could include posters, "radio ads" for school announcements, and print ads for student newsletters. Be creative!

PROJECT

8

WHERE IN THE WORLD?

The National Geographic Society defines geography as "a field of knowledge that deals with the Earth and all the life on it." Geography, then, is much more than maps and places. To know the geography of a place means to understand the physical, cultural, political, economic, historical, and environmental facts about it.

Making a Map

Divide your class into cooperative groups, and have each group design and make a world map. Each group may make a map or all the groups in the class may make one huge map. Look at a world atlas before you begin to see how cartographers (map makers) design maps. What kinds of things do they include? Decide how large you want your map to be. Size your map to scale so that the relative sizes of the continents and countries are in proportion to one another. Use different colors to distinguish countries from each other. Include a legend to identify mountains, deserts, bodies of water, and other physical features. Plan to use magazine photographs and drawings to illustrate your map.

Researching Your World

Each group should research just one part of the world. Use natural history magazines, library references, and atlases to find interesting facts about your region that your classmates won't already know. Look for features that are unique to your part of the world. For example, your region may include the largest desert or the largest body of water. It may have the least populated country or the country with the greatest rainfall. Does it include countries that

GREENLAND
NORTH AMERICA
UNITED STATES
SOUTH AMERICA
BRAZIL
EUROPE
AFRICA
AUSTRALIA
CHINA
COSMOPOLITAN
World

have changed names? Place names frequently change as political situations change. The Soviet Union has separated into many smaller republics that have reclaimed their old names. The country that was once Upper Volta changed its name to Burkino Faso after it gained independence.

Put the World Together

After your group has finished its research, you will have more information than you can include on one map. Decide what will go on the map and how the class groups will share what they've learned.

Where Are You?

Put all your information on cards for a geography game. Have each group write ten "clues" using their cards. After all groups have assembled their clues, begin the game. One group should share a clue and another class group, working as a team, should figure out where in the world or what in the world is being described. Work out a scoring system. Several example clues are given in the next column.

- You are looking for a country that has the largest movie industry. Where should you look?
- You are looking for a place where there are brown bears, white bears, and where the Inuit people live. Where should you look?
- You are in the country that contains the world's largest opal mines. Where are you?

An Extension

Is It Imported?

How interdependent are the countries of the world? Investigate where manufactured items come from. Survey 20 to 30 items at home to find out where they were made. Chart your findings to show what countries are represented. Look at labels on food, and tags on clothing, appliances, games, and electronics. Locate these places on your map.

GLOSSARY

This glossary defines each key term that appears in **bold type** in the text. It also shows the page number where you can find the word used. Some other terms that you may need to look up are included, too. We also show how to pronounce some of the words. A key to pronunciation is in the table below.

PRONUNCIATION KEY

a . . . back (bak)	oh . . . go (goh)	sh . . . shelf (shelf)
ay . . . day (day)	aw . . . soft (sawft)	ch . . . nature (nay chur)
ah . . . father (fahth ur)	or . . . orbit (or but)	g . . . gift (gihft)
ow . . . flower (flow ur)	oy . . . coin (coyn)	j . . . gem (jem)
ar . . . car (car)	oo . . . foot (foot)	ing . . . sing (sing)
e . . . less (les)	ew . . . food (fewd)	zh . . . vision (vihzh un)
ee . . . leaf (leef)	yoo . . . pure (pyoor)	k . . . cake (kayk)
ih . . . trip (trihp)	yew . . . few (fyew)	s . . . seed, cent (seed, sent)
i (i + con + e) . . . idea (i dee uh), life (life)	uh . . . comma (cahm uh)	z . . . zone, raise (zohn, rayz)
	u (+ con) . . . flower (flow ur)	

A

abiotic (ay bi AHT ihk) **factors:** nonliving things in the environment, including soil, water, temperature, air, light, wind, and minerals. (607)

acid rain: rain that combines with sulfur dioxide and nitrogen oxide in the air to form sulfuric acid and nitric acid and then falls to Earth. (268)

active immunity: immunity caused by the body making its own antibodies. (564)

active transport: movement of material through a cell membrane with the use of energy. (58)

adaptation: any characteristic of an organism that helps it to survive in its environment. (8)

adolescence: the period in human growth that begins around ages 12 to 14 and lasts until age 20. (542)

adulthood: the period in human growth that begins with the end of adolescence (age 20) and extends to old age. (542)

aerobic: requiring oxygen for respiration. (190)

aggression: a forceful act used to dominate or control another animal. (401)

AIDS: acquired immune deficiency syndrome, a fatal communicable disease caused by an RNA virus; spread by sexual contact, by use of contaminated needles, through the placenta or by nursing by an AIDS - infected mother. (186)

algae: plantlike protists that contain chlorophyll and make their own food; they have no roots, stems, or leaves and live in or near water. (203)

alleles (uh LEE LZ): the different forms a gene may have for a trait. (106)

allergens: substances that cause an allergic response in the body. (572)

allergy: a strong reaction of the immune system to a foreign substance. (572)

alternation of generations: in some protists and in plants, a cycle that alternates between sporophyte and gametophyte generations. (238)

alveoli (al VE uh li): in the lungs, clusters of tiny thin-walled sacs where oxygen and carbon dioxide are exchanged. (490)

Alzheimer's disease: a disease of unknown cause in which nerve cells in the brain fail to communicate with each other, causing memory loss. (520)

amino (uh MEE noh) **acids:** the building blocks of proteins. (443)

amniote egg: a type of egg that provides a complete environment for the developing embryo. (364)

amniotic sac: a thin membrane surrounding an embryo, filled with amnion (a clear liquid). (537)

amphibian: a cold-blooded vertebrate whose permeable skin, strong skeleton, and hibernation or estivation abilities adapt it to life in water and on land; examples are frogs, toads, salamanders. (356)

anaerobic: describes organisms that can't live in environments with oxygen. (190)

angiosperm: a vascular plant in which the seed is enclosed in a fruit, such as an apple. (256)

anorexia nervosa: an eating disorder in which a person eats very little to avoid gaining weight; it causes extreme weight loss that can damage organs and cause death. (456)

antibiotic: a drug used to kill bacteria. (194)

antibody: a substance made by the body in response to an antigen. (564)

antigens: proteins and chemicals that are foreign to the body. (564)

antiseptic: a substance that kills bacteria on living tissue. (559)

anus: an opening at the end of the digestive tract through which solid wastes leave the body. (317)

appendages: structures growing from the body, such as arms and legs. (332)

arteries: vessels that move blood from the heart. (466)

Arthropoda (AR thruh pahd uh): largest animal phylum; includes insects, shrimp, spiders, and centipedes. (332)

asci: the spore-producing sacs of sac fungi. (213)

asexual reproduction: reproduction in which a new organism is produced from a single parent. (80)

asthma: a disorder in which the bronchial tubes contract rapidly, causing shortness of breath or coughing; caused by smoking, allergy, or stress. (493)

atherosclerosis (ath uh roh skluh ROH sus): a circulatory system disorder in which fatty deposits form on artery walls and restrict blood flow. (468)

atria (AY tree uh): the two upper chambers of the human heart *(singular:* atrium). (464)

auxin (AHKS ihn): a plant hormone that causes plants to grow or bend toward light. (283)

axon: the part of a neuron that carries messages away from the cell body. (509)

B

basidium: the club-shaped spore-producing structure of club fungi. (214)

behavior: the way an organism acts toward its environment. (394)

bilateral symmetry: describes animals that have body parts arranged in the same way on both sides of their body. (304)

binomial nomenclature: the system of naming all organisms with two words; *Homo sapiens.* (157)

biodegradable: a substance that easily decomposes in the environment, usually by bacteria or fungi breaking it down into its basic elements. (66)

biogenesis: the theory that living things can be produced only from other living things. (11)

biological indicators: organisms that reflect the condition of the environment. (361)

biome (BI ohm): a large geographic area that has similar climates and climax communities. (632)

biosphere: all areas of Earth where life exists, including air, land, and water. (606)

biotic (bi AHT ihk) **factors:** living things in the environment, such as plants and animals. (606)

bladder: a bag-shaped muscular organ that stores urine until it leaves the body. (499)

blood pressure: pressure of blood in arteries. (467)

bog: low-lying, spongy, wet ground composed mainly of dead and decaying plants. (246)

brainstem: the part of the brain extending from the cerebrum to the spinal cord; controls involuntary muscle movements. (511)

bronchi: two tubes off the trachea that carry air into the lungs *(singular:* bronchus). (490)

budding: a type of asexual reproduction in which a new organism grows from the body of its parent; for example, yeast reproduces this way. (213)

bulimia (buh LEE mee yuh): an eating disorder in which a person eats huge amounts of food and then vomits to prevent weight gain. (456)

C

cambium (KAM bee um): tissue in vascular plants that grows to produce new xylem and phloem cells. (260)

camouflage: an adaptation that allows an animal to hide by blending into its surroundings. (613)

cancer: a major chronic disease resulting from uncontrolled cell growth. (571)

capillaries: microscopic blood vessels that connect arteries and veins; nutrients, oxygen, and wastes are exchanged through their one-cell-thick walls. (466)

carbohydrates: organic compounds that provide most of the body's energy; made up of carbon, hydrogen, and oxygen. (56, 443)

carbon-oxygen cycle: the continuous movement of carbon dioxide and oxygen between Earth's surface and the air. (618)

cardiac muscle: involuntary muscle tissue found only in the heart. (427)

carnivore: an animal that eats only other animals, such as a cat. (380)

carotenoids (kuh ROT uh noydz): red, yellow, or orange pigments found in plant-cell chloroplasts and in all cyanobacteria. (231)

carrying capacity: the number of animals that can obtain food and shelter from the environment in a given area; the ability of an environment to support its animal population. (407)

cartilage: a thick, tough, smooth, flexible tissue that is harder than flesh but softer than bone (like your ears); it covers the ends of bones to allow movement and cushion shock. (352, 422)

catalase: enzyme that breaks down hydrogen peroxide.(545)

cell: the smallest unit of an organism that can perform life functions. (6)

cell membrane: the selectively permeable outer boundary of a cell that allows food and oxygen to move into the cell and wastes to leave it. (37)

cell theory: a major theory of life science: all organisms consist of cells; cells are basic units of structure and function in organisms; and all cells come from other cells. (34)

cellulose: the organic compound that forms plant cell walls; made up of long chains of sugar molecules. (233)

cell wall: a rigid structure made of cellulose that surrounds a plant cell membrane to support and protect it. (41)

central nervous system: part of the body's control system, including the brain and spinal cord. (510)

centromere: a knotlike region that holds double-stranded chromosomes together. (76)

cerebellum: the part of the brain that coordinates muscle movements. (510)

cerebrum: the largest of the three parts of the brain; interprets impulses from the senses, stores memory, and controls voluntary muscles. (510)

chemical digestion: processing of food by fluids in the mouth, stomach, and small intestine, to break down large molecules into smaller ones that can be absorbed by cells. (451)

chemotherapy: the use of chemicals to destroy cancer cells. (571)

childhood: the period in human growth from age one to age 12. (541)

chitin: a strong, flexible carbohydrate forming the cell walls of hyphae and found in the body-covering and wings of insects. (211)

chloroplast: a plant cell organelle in which light energy is changed into chemical energy in the form of sugar during the process of photosynthesis. (41)

chordate: a member of the animal phylum Chordata that has a notochord, a hollow dorsal nerve cord, and gill slits at some time in its life cycle. (350)

chromatin: long strands of DNA in a cell's nucleus; chromatin coils into the form of chromosomes when a cell divides. (38)

chromosomes: threadlike strands of DNA and protein in a cell nucleus that carry the code for the inherited characteristics of an organism. (76)

chronic bronchitis: a disease in which too much mucus is produced in the bronchial tubes. (493)

chronic disease: a noncommunicable disease that lasts a long time. (570)

chyme (KIME): the thin, watery liquid in the digestive tract; partially digested food. (453)

cilia: short, hairlike structures that extend from the cell membrane and help tiny organisms move; found in respiratory passages. (207)

circadian rhythm: behavior that recurs on a 24-hour cycle. (404)

class: the third-highest taxonomical category, below a phylum (animals) or division (plants). (163)

classify: to group ideas, information, or objects, based on their similarities. (156)

clear-cut: the removal of all trees from an area of land. (360)

climate: the average weather in an area, determined by rainfall, temperature, and sunlight. (632)

climax community: a stable community with a balance of abiotic and biotic factors. (631)

closed circulatory system: a blood-circulation system using vessels to transport blood to the internal organs, as in humans. (326)

cnidarians (ni DAIR ee uhnz): a phylum of animals having stinging cells. (311)

cocaine: a highly addictive stimulant drug made from the leaves of the South American coca plant. (589)

cochlea (KOH klee uh): a sound-sensitive structure in the inner ear; shaped like a snail's shell. (516)

coevolution: occurs when two species evolve structures and behaviors in response to changes in each other over a long period of time. (286)

cold-blooded: describes an animal whose body temperature varies with the temperature of its surroundings. (351)

collar cells: cells that line the inside of a sponge and help water move through the sponge. (309)

communicable disease: a disease that is transmitted from one organism to another. (560)

communication: an exchange of information among animals, by means of cries, movements, touch, speech, pheromones, and so on. (403)

community: all the populations of different species that live in the same place at the same time. (610)

competition: the striving among organisms for the existing food, water, and living space available in an ecosystem; competition determines the size and location of populations. (612)

compound light microscope: an instrument that uses lenses to magnify objects. (31)

conditioning: modifying behavior so that a response previously associated with one stimulus becomes associated with another stimulus. (398)

conservation: the wise and careful use of Earth's resources. (654)

consumers: organisms that can't make their own food. (63)

contour feathers: on birds, the strong feathers that give birds their coloring and sleek shape. (372)

control: in an experiment, the standard for comparison. (15)

controlled burns: managed forest fires set periodically to control vegetation and plant debris underneath the dominant forest tree species. (620)

coronary circulation: the flow of blood to heart tissues. (467)

courtship behavior: behaviors that help males and females of a species prepare for mating. (402)

crack: a strong form of cocaine. (590)

crop: in an earthworm, a sac in the digestive system that stores soil eaten by the worm. (328)

cuticle: a waxy protective layer on stems and leaves of a plant that helps the plant conserve water. (233)

cyanobacteria (si AN oh bak TEER ee uh): bacteria that make their own food from sunlight; often a blue-green color. (191)

cyclic behaviors: innate behaviors that occur in a repeating pattern. (404)

cyst: a young, parasitic worm with a protective covering. (318)

cytoplasm (SI toh plaz uhm): the fluid material inside the cell membrane that contains structures that carry out life processes. (38)

D

day-neutral plant: a plant that isn't very sensitive to the length of darkness and thus can flower over a wide range of days. (284)

deforestation: destruction of Earth's forests. (164)

dendrite: the portion of a neuron that receives messages and sends them to the cell body. (509)

depressant: a substance that slows the central nervous system, affecting judgment, reasoning, memory, and motor control. (584)

dermis: the inner layer of skin; it contains blood vessels, nerves, and sweat glands. (433)

development: the changes living things undergo. (8)

diaphragm (DI uh fram): a muscle beneath the lungs that helps move air in and out of the body. (490)

dichotomous key: a step-by-step guide to identifying an organism, requiring the choice of one of two descriptions at each step. (168)

dicots (DI kahts): angiosperms having two seed leaves inside their seeds; for example, maple trees. (256)

diffusion: the movement of molecules move where they are concentrated to where they are less concentrated; a type of passive transport in cells. (58)

digestion: the process that breaks down food into small molecules that can be absorbed. (451)

diploid chromosome number: in organisms that reproduce sexually, the total number of paired chromosomes in a body cell of the organism. (83)

disinfectant: a substance that kills bacteria on nonliving objects. (559)

division: the second-highest of the taxonomical categories in the plant kingdom (in the animal kingdom, the word *phylum* replaces division.) (163)

DNA: *d*eoxyribo*n*ucleic *a*cid; an acid in the nuclei of cells that codes and stores genetic information; consists of strands of molecules that control cell activities using coded instructions. (86)

dominant: the form of a trait that appears to dominate or mask another form of the same trait. (108)

dorsal nerve cord: a bundle of nerves that lies above the notochord in a chordate animal; the spinal cord in most vertebrates. (350)

down feathers: on birds, the soft, fluffy insulating feathers that cover their skin. (373)

drug: any chemical substance that changes the way a person thinks, feels, or acts. (580)

drug abuse: deliberate use of a drug for other than its intended purpose. (580)

drug misuse: use of a drug for the purpose it was made, but taking it improperly. (580)

E

echinoderms (ih KI nuh durmz): spiny-skinned invertebrate animals that live on the seafloor, including sea stars and sand dollars. (342)

ecology: the study of relationships between organisms and their environments. (23)

ecosystem: a community interacting with the nonliving (abiotic) parts of its environment. (611)

egg: in organisms that reproduce sexually, the gamete from the female parent. (82)

electron microscope: an instrument using beams of electrons that magnifies objects too small to be seen with a light microscope. (32)

embryo: a fertilized egg during early growth; in humans, a fertilized egg during the first two months of pregnancy. (537)

embryology: the study of embryos, which are the earliest stages of an organism's development. (142)

emphysema (em fuh SEE muh): a disease in which the alveoli in the lungs lose their ability to expand and contract, mostly caused by smoking. (492)

endangered species: one whose population is so small that it is in danger of extinction. (144)

endocytosis: a process by which cells transport a large body, such as a large protein molecule, through the cell membrane into the cytoplasm. (60)

endoplasmic reticulum (end oh PLAZ mihk re TIK yew luhm): a cell organelle consisting of folded membranes that move materials around within the cell. (39)

endoskeleton: the internal skeleton of an organism that supports and protects the internal organs and provides a frame for muscles. (351)

endospore (EN doh spor): a thick-walled cell that some bacteria produce around themselves, especially for protection from heat and drought. (194)

energy pyramid: a model of the flow of energy in a food chain; less energy is available at each level of the pyramid as you move toward the top. (615)

environmental activists: people who work to conserve Earth's resources and protect the environment. (660)

environmental management: conserving resources and protecting ecosystems by carefully managing their use. (658)

enzyme (EN zim): a protein that speeds chemical reactions in cells without being changed itself. (57)

epidermis: the surface or outer layer of the two layers of skin. (432)

epiphyte: a plant that grows on other plants for physical support. (242)

equilibrium: condition in which the number of molecules of a substance is maintained at the same amount throughout a space. (59)

erosion: the wearing away of soil by wind, water, and ice. (651)

estivation: an adaptation for survival in hot, dry weather during which an animal becomes inactive and all body processes slow down. (356)

estuary: the area where a freshwater river or stream meets the ocean; examples are salt marshes, deltas, and mud flats. (638)

ethnobotany (eth noh BAH tuhn ee): the study of tribal people and their use of plants. (288)

eukaryote: an organism or cells with a formed nucleus and organelles surrounded by membranes. (161)

evolution: changes that occur over time in the hereditary features of organisms. (130)

exocytosis: a process by which a cell moves large molecules out through the cell membrane. (60)

exoskeleton: on all arthropods, the hard, lightweight external covering that shields, supports, and protects their bodies. (333)

extinction: the dying out of an entire species. (144)

F

family: the fifth-highest taxonomical category, below an order. (163)

fats: nutrients that release energy; also help the body store some vitamins. (444)

fermentation: a process by which yeast and some bacteria release energy needed for life processes by breaking down glucose into alcohol and carbon dioxide, without the use of oxygen. (65, 584)

fertilization: in organisms that reproduce sexually, the fusion of two gametes. (83)

fetus (FEE tus): a developing embryo; in humans, after the first two months of pregnancy. (538)

filter feeder: an organism that obtains food by filtering it from the water in which it lives. (309)

fins: fanlike structures on fish; adapted for steering, balancing, and moving through the water. (351)

fish: a cold-blooded vertebrate whose gills, fins, and scales adapt it to living in water. (351)

fission: a reproduction method used by bacteria in which one divides to form two bacteria having identical genetic material. (189)

flagellum (fluh JELL uhm): a whiplike tail on bacteria and some protists that helps them move through a moist environment. (189)

food chain: the feeding relationships that transfer energy through a community; starts with producers and moves through herbivores to carnivores. (614)

food group: a group of foods containing the same nutrients; for example, the meat group. (448)

food web: a series of overlapping food chains. (614)

fossils: remains of life from an earlier time. (137)

fracture: a break in a bone. (422)

free-living: organisms that find their own food and place to live without depending on other organisms; the opposite of a parasite. (315)

frond: the leaf of a fern. (244)

G

gametophyte: the form of a plant that produces male and/or female gametes. (237)

gene: the region of DNA that directs the making of a specific protein, thus controlling traits that are passed to offspring. (89)

genetic engineering: experimental methods for altering genes in offspring, to produce desirable traits or eliminate undesirable traits. (121)

genetics: the study of how a gene affects the traits of an offspring. (106)

genome: a map of the location of individual genes on every chromosome of an individual. (122)

genotype: the combination of dominant and/or recessive genes (alleles) present in the cells of an organism. (110)

genus: the second-largest taxonomic category. (157)

gestation period: the time between fertilization and the birth of an offspring. (381)

gill: in water-dwelling creatures, a breathing organ that extracts oxygen from the water. (324)

gill slits: paired openings in the throat; in fish, they develop into gills for breathing under water. (351)

gizzard: in an earthworm, a muscular structure in the digestive system that grinds up soil. (328)

Golgi (GAWL jee) **bodies:** cell organelles consisting of stacks of membrane-covered sacs that pinch off and move proteins to the outside of the cell. (39)

gradualism: a model that describes evolution as working steadily, gradually, and continuously to slowly change species into new species. (135)

greenhouse effect: the process by which heat radiated from Earth's surface is trapped and reflected back to Earth by gases in the atmosphere, causing worldwide temperatures to increase. (649)

guard cells: in a plant leaf, cells that surround the stomata to open and close them. (261)

gymnosperm: a vascular plant that produces seeds on the scales of cones, such as pine cones. (255)

H

habitat: the place where an organism lives within a community. (610)

hallucinogens (huh LEWS un uh junz): drugs that affect the user's perception of the world, causing reality to be confused with fantasy. (591)

haploid chromosome number: in organisms that reproduce sexually, the number of chromosomes in a gamete. (83)

hashish: a drug that is more concentrated and powerful than marijuana. (588)

hemoglobin: a chemical in red blood cells that carries oxygen to tissues and gives blood its red color. (472)

herbivore: an animal that eats only plants. (380)

heredity: passing traits from parent to offspring. (106)

hermaphrodite: an animal that produces both sperm and eggs. (310)

heroin: a powerful pain-relieving drug made from morphine; it is highly addictive. (592)

heterozygous (het uh roh ZI gus): an organism that has two different alleles for a trait. (110)

hibernation: an adaptation for winter survival during which an animal becomes inactive and all body processes slow down. (356)

homeostasis: an organism's or cell's constant adjustment to maintain stable conditions in itself, despite changes in its environment. (7)

hominids: earliest humanlike primates; eat both meat and vegetables and walk upright on two feet. (147)

homologous: body parts in different species but which are similar in origin and structure, such as limbs on different animals. (141)

Homo sapiens: our own species, a hominid primate mammal. (148)

homozygous (ho muh ZI gus): an organism that has two identical alleles for a trait. (110)

hormones: secretions from endocrine glands that control certain body activities. (522)

hypertension (hi pur TEN chun): a circulatory disorder in which blood pressure is too high. (468)

hyphae (HI fee): masses of threadlike structures that form the body of a fungus. (211)

hypothesis: a prediction that can be tested. (14)

I

immovable joint: a juncture of two or more bones, made so that no movement occurs. (423)

immune system: a complex group of defenses that the body uses to fight disease. (563)

imprinting: a type of learning in which an animal forms a social attachment to another organism during a specific period after birth or hatching. (397)

incomplete dominance: a condition that exists when both alleles for a trait are expressed. (114)

incubate: to keep an egg or newborn animal warm; the heat helps eggs develop until they hatch and helps young to survive. (372)

infancy: the period in human growth from four weeks after birth to one year. (541)

innate behavior: behavior that an organism has when it is born and does not have to learn. (394)

insight: a form of reasoning that enables animals to use past experiences to solve new problems. (399)

instinct: a complex pattern of innate behavior involving multiple actions. (395)

interferon (ihn tuhr FEER ahn): a protein produced in animal cells that blocks viruses from reproducing in other cells. (184)

interneurons: nerve cells throughout the brain and spinal cord that transmit impulses from sensory neurons to motor neurons. (509)

invertebrate: an animal without a backbone. (303)

involuntary muscle: a muscle that can't be consciously controlled, such as heart and digestive muscles. (426)

J

joint: any place where two or more bones meet. (423)

K

kidneys: two organs that filter blood to produce the waste liquid called urine. (498)

kingdom: the highest of the taxonomic categories, having the largest number of species; kingdoms include all other categories. (156)

L

larva: a stage in development between egg and adult. (310)

larynx: the structure between the pharynx and trachea to which the vocal cords are attached. (489)

latent virus: a virus that becomes part of a cell's DNA and lies dormant until something causes it to become active, whereupon it destroys the cell and makes new viruses. (183)

law: a rule that describes a pattern in nature and what will happen under specific conditions. (16)

learning: the process of developing a behavior through experience; an organism repeats behaviors that fulfill a need and avoids those that achieve nothing or cause pain. (396)

lichen: a fungus living in a mutualistic relationship with green algae. (215)

life span: the length of time an organism lives. (8)

ligament: a tough band of tissue that holds bones together. (423)

limiting factor: a condition, such as the quality or amount of water or food, that determines whether an organism, population, or species survives in its environment. (628)

lipid: an organic compound that stores and releases large amounts of energy; fats or oils. (57)

littoral (LIHT uh rul) **zone:** the ocean zone along the shore that is covered with water during high tide and exposed to air during low tide. (637)

liverwort: a simple, rootless, nonvascular plant having a flattened, leaflike body. (236)

long-day plant: a plant that requires short nights (long days) to flower. (284)

lymph (LIHMF): fluid in body tissues made up of water, dissolved substances, and lymphocytes. (480)

lymphatic (lihm FAT ihk) **system:** collects fluid from body tissues and returns it to the blood through lymphatic vessels. (480)

lymph node: structures throughout the body that filter microorganisms and foreign material from lymph before it returns to blood. (481)

lymphocyte (LIHM fuh site): a white blood cell that fights disease-causing antigens by engulfing and digesting them. (481, 566)

lysosome (LI suh sohm): an organelle with chemicals that digest waste and worn-out cell parts. (40)

M

mammal: a warm-blooded vertebrate with insulating hair and mammary glands. (379)

mammary glands: glands in female mammals that produce milk for feeding young. (379)

manatee: a large, saltwater mammal living in warm coastal waters; commonly called a sea cow. (386)

mantle: in a mollusk, the outside covering of the soft body; it secretes chemicals that become the shell or protects the body if no shell exists. (324)

marijuana: a drug made of stems, leaves, flowers, and seeds of Indian hemp; also called pot. (588)

marrow: a red or yellow fatty tissue in certain bones that produces red and white blood cells. (422)

marsupial: a mammal with a pouch on its abdomen for carrying and nursing its young. (381)

mechanical digestion: processing of food by chewing, by churning, and by the action of bile, to break it into smaller particles. (451)

medusa: a cnidarian (stinging-celled animal) that is bell-shaped and free-swimming. (312)

meiosis: the division of the cell nucleus to produce sex cells (gametes). (82)

melanin (MEL uh nuhn): a chemical produced by the epidermis that gives skin its color. (433)

menopause: in older females, the period of years when the menstrual cycle becomes irregular and eventually stops. (533)

menstrual (MEN strul) **cycle:** in females, the cycle of egg production and menstruation. (532)

menstruation (men STRAY shun): in females, the monthly discharge through the vagina of the lining of the uterus and some blood if fertilization of an egg has not occurred. (533)

metabolism: all of the changes in an organism that enable it to live, grow, and reproduce. (63)

metamorphosis: in insects, the changes of form during the life cycle: egg, larva, pupa, adult. (337)

methamphetamine (meth am FET uh men): a very powerful stimulant. (587)

migration: the instinctive seasonal movement of animals, such as birds flying south for the winter. (405)

mimicry: a defense against predators in which an animal copies the appearance or behavior of another organism. (613)

minerals: inorganic nutrients that regulate chemical reactions in the body, such as building cells and sending nerve impulses. (446)

mitochondria (mi toh KAWN dree uh): a cell organelle that breaks down food molecules and releases energy. (40)

mitosis: the process by which a nucleus divides into two nuclei, each containing the same number of chromosomes that the parent cell had. (75)

mollusk: a soft-bodied invertebrate that usually has a shell, such as a snail. (324)

molting: in animals, the periodic shedding and replacing of the old body covering, such as skin or an exoskeleton. (333)

monocots (MAHN uh kahts): angiosperms having a single seed leaf inside their seeds. (256)

monotreme: a mammal that lays eggs having a tough, leathery shell; for example, the platypus. (382)

moss: a simple, rootless, nonvascular plant with leaflike growths that spiral around a stemlike structure. (236)

motivation: some stimulus within an animal that causes it to act. (398)

motor neurons: nerve cells that conduct impulses from the brain or spinal cord to muscles or glands throughout the body. (509)

movable joint: a place where two or more bones meet or are attached and allow movement. (423)

mRNA: *m*essenger *r*ibo*n*ucleic *a*cid, a nucleic acid produced from DNA that begins protein construction. (90)

mutation: any permanent change in the genetic material (DNA) of a cell. (91)

multiple alleles: having more than two alleles that control a trait. (115)

muscle: tissue that can relax and contract to allow movement. (426)

mutualistic: a relationship in which two organisms live together; both benefit in some way. (215)

N

natural resources: raw materials in the environment that organisms use for survival, such as air, water, soil, and forests. (648)

natural selection: Darwin's theory that organisms best adapted with traits for an environment will survive to pass on those traits to their offspring. (132)

nephron (NEF rahn): the filtering unit of the kidney. (499)

neurons: nerve cells that carry impulses throughout the body. (509)

niche: the role of a species within a community. (610)

nitrogen cycle: the continuous movement of nitrogen from the atmosphere, to plants, and back to the atmosphere (or directly into plants) again. (619)

nitrogen dioxide: a major air-polluting chemical in cigarette smoke and automobile exhaust that is harmful when inhaled. (496)

nitrogen-fixing bacteria: bacteria that change nitrogen in the air into nitrogen compounds that are useful to plants and animals. (194)

noncommunicable disease: a disease that cannot be spread from one organism to another. (570)

nonrenewable resources: natural resources that are available only in limited amounts and are not being replaced by nature. (648)

nonvascular plant: a plant lacking tube-like vessels to transport food and water; it absorbs water directly through its cell membranes. (234)

notochord: a flexible, rodlike structure along the dorsal side (back) of a chordate animal; the backbone in vertebrates. (350)

nucleic acids: large organic molecules that store important information in cells and direct their activities; two types are DNA and RNA. (57)

nucleus: a structure inside a cell that directs the cell's activities; contains chromatin; chromosomes in a dividing cell. (38)

nutrients: the chemicals in foods that provide energy and materials for life activities. (442)

O

olfactory cells: nerve cells in the nasal passages that respond to chemical stimuli in air. (517)

omnivore: an animal that derives its energy from both plants and other animals. (380)

open circulatory system: a blood-circulation system that lacks vessels and instead bathes internal organs in blood, as in mollusks. (324)

order: the fourth-highest taxonomical category, below a class. (163)

organ: a structure made up of different types of tissues that work together to do a specific job; for example, the heart. (45)

organelles: membrane-bound structures within the cytoplasm of eukaryotic cells; organelles break down food, move wastes, and store materials. (38)

organism: a living thing that is made of one or more cells, uses energy, moves, responds to its environment, reproduces, adapts, and has a life span. (6)

organ system: a group of organs working together for a specific job; for example, the digestive system. (45)

osmosis: the passive transport of water through a cell membrane by diffusion. (59)

ovary: in angiosperms, the swollen base of the pistil, where ovules form (264); in female animals, the organ that produces ova, or egg cells. (531)

ovulation (ahv yuh LAY shun): in human females, the monthly release of an egg from an ovary. (531)

ovule (OHV yewl): the reproductive part of a female plant that contains the eggs. (262)

P

palisade (pal uh SAYD) **layer:** in a plant leaf, rows of closely packed cells that are near the surface and contain chlorophyll. (261)

parasite: usually an organism, but anything that obtains food from a host organism and at the same time harms the host organism. (183)

passive immunity: immunity caused by antibodies introduced from an outside source. (564)

passive transport: movement of material through a cell membrane without the use of energy. (58)

pasteurization: heating food to a temperature below boiling long enough to kill most bacteria. (559)

pathogen: any organism that causes disease. (194)

pedigree: a diagram that traces the history of a trait in a family. (119)

pelagic zone: the open ocean just beyond the sublittoral zone. (638)

periosteum (per ee AHS tee uhm): a tight-fitting membrane covering bone. (421)

peripheral nervous system: part of the nervous system, including cranial nerves and spinal nerves that connect the brain and spinal cord to other body parts. (510)

peristalsis (pe ruh STAHL sihs): contractions that move food through the digestive system. (452)

permafrost: in tundra areas of Earth, the deeper soil that remains permanently frozen underneath the topsoil layer. (633)

pesticide: a chemical that kills undesirable plant or animal pests. (340)

pharynx (FER ingks): a tubelike passageway for both food and air, located between the nasal cavity and the esophagus. (489)

phenotype (FEE nuh tipe): a physical trait in an organism; resulting from its genetic makeup. (110)

phloem (FLOW em): tubular cells in vascular plants that move food from leaves and stems to other parts of the plant for use or storage. (260)

photoperiodism: the flowering response of a plant to change in the length of day and night. (284)

photosynthesis (foht oh SIHN thuh sus): a chemical reaction used by producers, such as green plants, to produce food; light energy is used to produce chemical energy, converting carbon dioxide and water into sugar and oxygen. (63, 278)

phylogeny: the evolutionary history of an organism. (160)

phylum: the second-highest of the taxonomical categories in the animal kingdom. (163)

physical dependence: taking a drug because the body has a chemical need for it and can't function without it; also called addiction. (581)

pioneer species: the first plants to grow in a new or disturbed area; their decay creates material on which other plant species grow. (239)

pistil (PIHS tul): the female reproductive organ of a flower. (264)

placenta: part of the sac that surrounds an embryo in mammals; attached to the uterus; many blood vessels provide life support for an embryo. (381)

placental mammal: a mammal whose young develop inside the female in a uterus. (381)

plasma: the liquid part of blood, made mostly of water but also containing dissolved nutrients, minerals, and gases such as oxygen and carbon dioxide. (472)

platelet: a cell fragment that helps blood clot. (472)

poaching: illegal hunting of animals. (386)

pollen grain (PAHL un GRAYN): the reproductive part of a male plant that contains the sperm. (262)

pollen tube: a hollow structure that grows from a pollen grain into an ovule, through which a sperm swims into the ovule for fertilization. (262)

pollination: the transfer of pollen grains from the stamen to the ovule. (264)

polygenic (pahl ih JEHN ihk) **inheritance:** groups of gene pairs act together to produce a trait. (116)

polyp: a cnidarian (stinging-celled animal) that is tube-shaped and sessile. (312)

population: organisms of one species living in the same place at the same time. (134, 608)

population density: the number of individuals per unit of living space. (608)

Porifera: the phylum to which sponges belong; the name means "pore-bearing." (308)

predator: an organism that kills and eats prey to obtain energy. (352)

pregnancy: period between fertilization and birth. (536)

preening: a behavior of birds in which a bird uses its beak to rub oil over its feathers to condition them and make them water repellent. (373)

prey: an organism that is eaten by a predator. (352)

primary succession: the development of new communities in newly created land areas, such as new volcanic islands. (629)

primates: the group of mammals to which monkeys, apes, and humans belong. (146)

probability: a branch of science that determines the likelihood of something happening. (109)

producers: green plants that make their own food by photosynthesis. (63)

prokaryote: single-celled organism that doesn't have an organized nucleus or organelles. (161)

protein: an organic compound made up of amino acids; used throughout the body for growth and to replace and repair cells. (57, 443)

prothallus: the structure in ferns that produces gametes. (244)

protists: members of the Kingdom Protista; simple organisms having cells with a nucleus; probable ancestors of the fungi, plant, and animal. (202)

protozoa (proht uh ZOH uh): one-celled animal-like protists; many are parasites. (206)

pseudopod (SEWD uh pahd): a footlike extension of cytoplasm used by some organisms to move and to trap food. (206)

psychological dependence: taking a drug only because you think that you need it. (581)

pulmonary (PUL mo ner e) **circulation:** the flow of blood from the heart, to the lungs, and back to the heart. (465)

punctuated equilibrium: a model that describes evolution as working rapidly, changing species to new species by the mutation of a few genes. (135)

Punnett square: a tool that shows how genes can combine; used to predict results in genetics. (110)

purebred: an organism that always produces the same traits in its offspring. (108)

R

radial symmetry: describes animals that have body parts arranged in a circle around a central point, similar to a bicycle wheel. (303)

radioactive elements: elements whose atoms give off radiation, a form of atomic energy. (138)

radula: in mollusks, a tongue-like organ with rows of teeth that scrape and tear food. (325)

recessive: the form of a trait that appears least often in offspring; for example, left-handedness is recessive compared to right-handedness. (108)

reflex: a type of innate behavior that is an automatic response to a stimulus; not involving the brain. (395, 512)

reforestation: replanting an area with seedling trees. (656)

regeneration: a type of asexual reproduction in which a whole new organism grows from just a part of the parent organism; a sea star. (309)

relative dating: estimating the age of a fossil by comparing it to younger fossils in the rock layer above and to older fossils in the rock layer below. (138)

renewable resources: natural resources that constantly are being replaced by nature. (648)

replication: the process by which DNA copies itself. (88)

reptile: a cold-blooded vertebrate that has dry, scaly skin and that lays eggs covered with a leathery shell; examples are lizards, snakes, turtles. (363)

respiration: a process by which some organisms release the energy they need for life processes by combining oxygen with glucose. (64, 279)

response: the reaction to a stimulus. (7)

retina: light-sensitive tissue at back of the eye. (515)

rhizoids: rootlike filaments containing only a few long cells; they hold moss plants in place. (236)

rhizome: the underground stem of a fern. (244)

ribosome: a cell organelle on which protein is made. (39)

S

saliva: the watery substance produced in the mouth that begins the chemical digestion of food. (452)

saprophyte (SA proh fite): any organism that uses dead material as a food and energy source. (193)

scales: hard, thin, overlapping plates that cover and protect a fish's body. (351)

scientific methods: problem-solving procedures used by scientists: define the problem, make a hypothesis, test the hypothesis, analyze the results, and draw conclusions. (14)

scrubber: a machine that blows water mist through gases in the smokestack of a fossil fuel-burning plant to remove sulfur dioxide and nitrogen oxide. (269)

secondary succession: the gradual return of a disturbed area to its former communities. (629)

sedimentary rock: a type of rock formed when fine particles like mud and sand settle out of water and become cemented together. (137)

semen: the mixture of sperm and a fluid that nourishes the sperm and helps them to move. (531)

sensory neurons: nerve cells that transmit stimuli from receptors to the brain or spinal cord. (509)

sessile: describes organisms, such as trees, that remain attached to one place during their lifetime. (308)

setae (SEE tee): in a segmented worm, bristle-like structures on the outside of the body that help it grip soil and move. (327)

sex-linked gene: an allele inherited on a sex chromosome. (119)

sexually transmitted diseases (STDs): diseases transmitted during sexual contact. (561)

sexual reproduction: a type of reproduction in which a new organism is produced by combining sex cells from two parents. (80)

short-day plant: a plant that requires long nights (short days) to flower. (284)

skeletal muscles: voluntary muscle tissue attached to bones; the muscles that makes the bones move. (427)

skeletal system: the body's network of bones, which form a rigid frame to support the body, protect internal organs, generate red blood cells, and store calcium and phosphorus. (420)

smooth muscle: involuntary muscle tissue that forms the walls of the stomach, intestines, uterus, and blood vessels. (427)

social behavior: interactions among organisms of the same species, including mating, caring for young, protection, getting food, and claiming territory. (403)

society: a group of animals of the same species living and working together in an organized way. (403)

solid wastes: solid products that can be recycled, burned, buried, or dumped. (651)

sori: structures that produce spores on the underside of fern fronds (*singular:* sorus). (244)

species: organisms whose members are alike and successfully reproduce among themselves. (130)

species diversity: the great variety of plant and animal species on Earth. (164)

sperm: the gamete or reproductive cell from the male parent, produced by the testes. (82, 530)

spiracles: in an arthropod, openings in the abdomen that allow oxygen and carbon dioxide to move into and out of the lungs. (333)

spleen: the largest organ in the lymphatic system; it filters blood and destroys old and damaged red blood cells. (481)

spongy layer: in a plant leaf, a layer of loosely arranged cells with xylem and phloem tissues; lies between the palisade layer and the lower epidermis. (261)

spontaneous generation: a belief that living things come from nonliving matter; for example, that frogs arise spontaneously from mud. (10)

sporangia: the round, spore-producing cases of zygote fungi. (212)

spore: a resistant reproductive cell that forms new organisms without fertilization; in fungi, ferns and some protists. (212)

sporophyte: a capsule in which spores are produced by meiosis in plants such as mosses. (237)

stamen (STAY mun): the male reproductive organ of a flower. (264)

steroid: a drug similar to testosterone; used to increase muscle mass; improves performance. (430)

stimulant: a substance that stimulates the central nervous system and speeds up other body systems; for example, the caffeine in coffee, tea, chocolate, and cola drinks. (583)

stimulus: anything an organism responds to, such as sound, light, heat, vibration, odor, movement, hunger, thirst, and so on. (7, 282)

stomata: in a plant leaf, small pores in the surface that allow carbon dioxide, water, and oxygen to enter and leave (*singular:* stoma). (261)

sublittoral zone: the shallow water above the continental shelf. (637)

succession: a gradual, orderly change of species in a community over time. (629)

symbiosis: a condition where two organisms live together for mutual benefit. (215)

synapse: the small space between two neurons across which impulses can travel. (510)

systemic (sihs TEM ihk) **circulation:** the flow of blood from the heart, to all body tissues (except lungs and heart), and back to the heart. (467)

T

target tissue: tissue affected by hormones. (522)

taste buds: tissue located on the tongue that responds to chemical stimuli. (517)

taxonomy (tak SAHN uh mee): the science of grouping and naming organisms. (156)

technology: the application of scientific knowledge to improve the quality of human life. (22)

tendon: a thick band of tissue that attaches a muscle to a bone. (427)

tentacles: the armlike structures that surround the mouths of some organisms and help them to capture food. (311)

territory: an area that an animal defends from other members of the same species. (401)

testes: organs in males that produce sperm. (530)

theory: description of nature; subject to change when evidence changes. (18)

thymus: lymph organ that produces lymphocytes; behind the sternum. (481)

tissue: similar cells that do the same sort of work; for example, all muscle tissue contracts. (45)

tolerance: occurs when the body adjusts to a drug and needs increasing doses to produce the same effect. (581)

toxin: a poison produced by disease-causing organisms (pathogens). (194)

trachea: a tube that carries air to the bronchi. (489)

transgenic organisms: organisms that contain genetic information from another species. (92)

transpiration: in plants, loss of water vapor through the stomata of a leaf. (277)

trial and error: behavior that is modified by experience. (397)

tRNA: *t*ransfer *r*ibo*n*ucleic *a*cid, a nucleic acid produced from DNA that picks up amino acids in the cytoplasm and transfers them to the ribosome. (90)

tropism: the response of a plant to a stimulus. (282)

tube feet: in an echinoderm, structures attached to the water vascular system that act like suction cups and help the echinoderm to move, feed, get oxygen, and get rid of waste. (342)

tumor: an abnormal growth of tissue. (571)

tundra (TUN drah): a cold, dry, treeless biome where the sun is barely visible during the six to nine months of winter. (633)

U

umbilical cord: a bundle of blood vessels connecting the placenta to the embryo's navel in mammals; carries nutrients and oxygen to the embryo. (381)

ureters (YOOR ut urz): tubes that lead from each kidney to the bladder. (499)

urethra (yoo REE thruh): a tube leading from the bladder to the outside of the body. (499)

urinary system: a system of excretory organs that rids blood of wastes, excess water, and excess salts. (498)

urine: waste liquid collected by the kidneys and containing water, salts, and other wastes. (499)

uterus: in females, the pear-shaped, muscular organ in which a fertilized egg develops into a baby; also called the womb. (531)

V

vaccination: administration of a weakened virus to develop immunity against a disease. (568)

vaccine: a solution made from a killed or weakened virus; causes artificial immunity. (184)

vacuole: a storage area in a cell for water, food, or waste products. (41)

vagina: in females, the passageway that leads from the uterus to outside of the female's body; also called the birth canal because offspring pass through it when being born. (531)

variable: in an experiment, the factor tested. (15)

variation: the occurrence of an inherited trait that makes an individual different from other members within the same species. (133)

vascular plant: a plant having tube-like vessels that transport food and water to its cells. (234)

vascular tissue: in vascular plants, tissue made up of long cells that form tubes. (241)

veins: vessels that move blood toward the heart, carrying wastes. (465)

ventricles (VEN trih kulz): the two lower chambers of the human heart. (464)

vertebrate: animal with a backbone. (303)

vestigial structure: a body part that is reduced in size and is no longer used by the organism. (141)

villi (VIHL i): tiny, fingerlike projections on the inner surface of the small intestine. (454)

virus: a microscopic particle made of either a DNA or an RNA core and covered with a protein coat; it infects host cells in order to reproduce. (182)

vitamins: organic nutrients that promote growth, regulate body functions, and help the body use other nutrients. (445)

voluntary muscle: a muscle you can control, such as arm and leg muscles. (426)

W

warm-blooded: describes an animal whose body temperature stays the same, regardless of temperature changes in its environment. (351)

water cycle: the continuous movement of water in the biosphere through evaporation, condensation, and precipitation. (617)

water table: the upper surface of underground water; this underground water supplies drinking water for most humans. (641)

water vascular system: a network of water-filled canals, unique in echinoderms. (342)

wetland: an area of land covered by shallow water at least part of the year; for example, marshes, swamps, and bogs. (640)

wildlife preserve: an area of land set aside to protect wildlife species. (656)

withdrawal: an illness that occurs when a person stops taking a drug on which the person is physically dependent. (581)

X

xylem (ZI lum): tubular vessels in vascular plants that transport water and minerals from the roots up through the plant. (260)

Z

zygote: in organisms that reproduce sexually, the cell that forms in fertilization. (83)

INDEX

The Index for *Merrill Life Science* will help you locate major topics in the book quickly and easily. Each entry in the Index is followed by the numbers of the pages on which the entry is discussed. A page number given in **boldface type** indicates the page on which that entry is defined. A page number given in *italic type* indicates a page on which the entry is used in an illustration or photograph. The abbreviation *act.* indicates a page on which the entry is used in an Activity.

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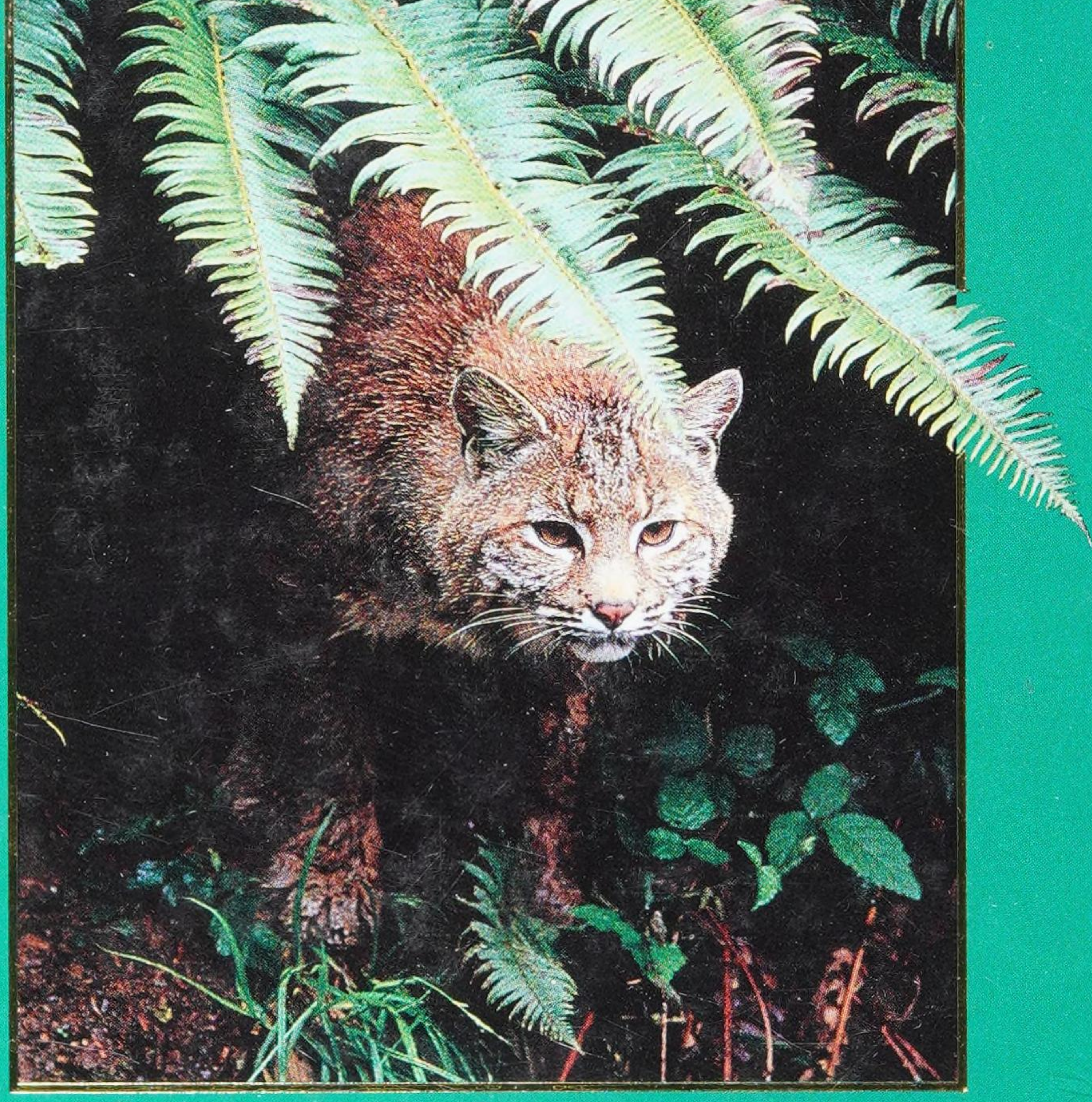

A lynx slips from under the cool protection of some ferns in late summer to refresh itself at a stream. This sturdy predatory cat usually lives alone and frequently hunts at night. Feeding on birds and small mammals, it helps keep rodent populations under control.

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